

Developing the Riyadh Strategic Microsimulation Model as a Novel Means of Exploring Policy Transfer and Future Transport Scenarios



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ABSTRACT

Within just 50 years, Saudi Arabia's capital city Riyadh has developed from being a walled town to a modern metropolis of eight million people (ADA, 2015). Riyadh is a unique case study. Due to cultural and climate factors, there are good reasons why road transport dominates, with more than 93% of journeys undertaken by car. Despite substantial investment in the road network, there is severe traffic congestion caused by population growth and increased economic activity. This has made transport in and around the city time-consuming, unsafe, unhealthy and ultimately unsustainable.

To address this, several high-profile projects are underway, most notably the Riyadh Metro, currently the world's most expensive metro project, with a total value of 88 billion SAR. This research is therefore timely. It attempts to answer why Riyadh's transport system has developed along its current lines, and whether schemes such as the Riyadh Metro will have the expected impact. To do this, the research had to operate from a strong multidisciplinary platform, linking transportation engineering, planning and urban studies to explore the issue of Policy Transfer as it applies to Riyadh. The Riyadh Metro is a paradigm case: it is a transport infrastructure that has proven successful in other (usually western) nations, and its application in Riyadh is expected to have similar benefits, despite the city's cultural and climatic uniqueness.

The research makes a substantial original contribution to knowledge by creating a strategic traffic microsimulation of Riyadh's city core, using policy transfer insights, and unique access to Saudi Arabian stakeholder input, to develop a set of future scenarios which can be subject to a direct test in the model. This model has been created and calibrated using Riyadh traffic and mapping data, and professionally audited by the microsimulation company SIAS Ltd.

One novel feature of the research is that this model is being used strategically. It enables four congestion indicators to be extracted under all network conditions, from free-flow conditions to complete saturation. These indicators are a) level of service, b) traffic

flow, c) journey time and d) queue length. The values of the respective indicators will be logged and these, in turn, will represent coordinates for a so-called Overall Performance Curve (OPC). The various OPCs show how each of the indicators performs under all traffic conditions, enabling predictions about all possible future states to be explored. In other words, this research provides a scientific platform for future expectations. That's where the policy transfer issues come in, by using the OPCs whatever the expectations, it will be on them somewhere, given that the OPC is like a formal scientific test-bed covering all scenarios and expectations.

The first scenario to be explored (Scenario 1) is the 'do nothing' option. Current forecasts show the existing road network will be fully saturated by 2021, with a forecasted additional 40% traffic volumes in the study area. This will result in already lengthy journey times increasing by a further 90%, and queue lengths by 120%. Clearly, 'doing nothing' is not a viable option in light of population growth and economic development. Riyadh transportation authorities are already acutely aware of this. One further pioneering aspect of this research is its ability to survey key Riyadh stakeholders to discover what alternative scenarios are being pursued and considered, and to gauge their expected outcomes. Scenarios 2, 3 and 4 pick up on these expectations and subject them to a direct test in the strategic microsimulation model.

As such, Scenario 2 embodies the current strategy involving the Riyadh Metro and examines the expected traffic reductions. According to the various OPCs, the Riyadh Metro will reduce the volume of cars on the road network by up to 43%. If these expectations arise in practice, journey times and queue lengths will be approximately halved compared with present conditions. The key, of course, is whether these expectations will in fact be met.

In summary, this thesis makes a number of new contributions to theory. These include a mapping of the existing policy transfer theory to the situation pertaining to Riyadh, and an extension of existing theory to take account of unique socio-cultural and climatic factors. Solutions cannot be proven to be effective in any society unless they are tested and implemented. Thus, this research provides an opportunity for engineers, city

planners, transport systems stakeholders/decision makers and beneficiaries to **SEE** the future in the present.

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DECLARATION STATEMENT

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LIST OF PUBLICATIONS

A) Academic participations

Type of publication	Title of publication	Date of publication	Place
Poster	Infrastructure and Environment Scotland Second Postgraduate Conference	Sep. 2, 2014	Edinburgh
Paper	International Conference Data Mining, Civil and Mechanical Engineering (ICDMCME'2015), ISBN 978-93-84422-07-3 available online: http://dx.doi.org/10.15242/IIE	Feb. 1-2, 2015	Bali
Paper	Urban Planning and Architectural Design for Sustainable Development (UPADSD)	Oct. 14-16, 2015	Lecce
Presentation	Microsimulation approach to study congestion reduction policies and implementation for Riyadh city (see Appendix B)	Dec. 22, 2015	ADA headquarters, Riyadh
Paper	Article: Riyadh Transportation History and Developing Vision, Reference: SBSPRO26870 Journal title: Procedia - Social and Behavioral Sciences. First author. Final version published online: 21-JAN-2016 http://www.sciencedirect.com/science/article/pii/S1877042815062047	Jan. 21, 2016	Procedia
Paper	A Novel Microsimulation Approach and a Comprehensive Traffic Flow. Analysis for the Road Network of Riyadh City	Abstract accepted	Procedia
Paper	Congestion reduction policies and implementation for growing cities – case study: Riyadh city	Abstract accepted	Procedia

B) Opinion articles

The following table presents the researcher opinion articles in the field of Saudi transport issues and his perspective.

Title	URL address	Date of publication
The cost of transportation in the most important city for Muslims Mecca	http://www.al-jazirah.com/2016/20161204/wz2.htm	04/12/2016
How we can serve the people in Mecca with some creative suggestions for transport	weam.co/437358	16/12/2-16
The benefits of the double decker train! And how we can have it as a solution for pilgrimage	weam.co/439265	02/04/2017
The role of transport in the humanization of cities " from Saudi perspective	weam.co/441209	26/12/2016
The quality of roads. Towards a Saudi national index global! - based on Level of service (LOS) stander	http://mobile.alweeam.com.sa/455943/	21/03/2017

TABLE OF ABBREVIATIONS

Abbreviation	Description
ABM	Agent-Based Modelling
ADA	Arriyadh Development Authority in Saudi Arabia
CBD	Central Business District
ECMT	European Conference of Ministers of Transport
GCC	Gulf Cooperation Council
GEH	Geoffrey E. Havers
GIS	Geographical Information Systems
ITS	Intelligent Transportation Systems
KAFD	King Abdullah Financial District
KAR	King Abdullah Road
KFR	King Fahd Road
LoS	Level of Service
MEDSTAR	Metropolitan Development Strategy for Arriyadh
MENA	Middle East and Northern Africa
MOMRA	Ministry of Municipal and Rural Affairs
MOT	Ministry of Transport in Saudi Arabia
NICHES	New and Innovative Concepts for Helping Transport Sustainability
O/D	Origin/Destination
OLS	Olaya Street
OPC	Overall Performance Curve
PMR	Persons with Reduced Mobility
PTA	Public Transport Authority in Saudi Arabia
PTNDP	Public Transit Network Design Problem
RNDP	Road Network Design Problem
RPTP	Riyadh Public Transport Project
RS	Remote Sensing
SAPTCO	Saudi Arabia Public Transport Company
SMM	Strategic Microsimulation Model for Riyadh City Centre

TM	Traffic Matrix
TOD	Transit-Oriented development
UTNDP	Urban Transportation Network Design Problems
VSL	Variable Speed Limits
VTPI	Victoria Transport Policy Institute

CHAPTER 1 INTRODUCTION

1.1 Riyadh: The Case Study Context

Riyadh is the capital city of the Kingdom of Saudi Arabia. In the space of just 50 years, it has developed from being a walled town to a modern metropolis. Riyadh today is an expanding modern city. It has seen a dramatic increase in population, according to General Authority for statistics in Saudi Arabia (2017), Riyadh population increased from 6.7 million in 2010 to 8 million in 2017. This is a rise of more than 16% over the past 7 years. This increase is primarily due to migration from surrounding villages and suburbs (United Nations Population Division, 2008). One notable side effect of this urban population explosion is the increasingly strained transportation system. Severe traffic congestion and road safety issues caused by population growth and increased economic activity has made transport in and around the city time-consuming, unsafe and unhealthy. This, in turn, limits future prosperity and quality of life (A. Abdullah, 2011). Figure 1.1 gives a sense of the problems the city faces.



Figure 1.1 Riyadh during rush hour (King Fahd Road) (Source; ADA, 2015)

Figure 1.1 shows King Fahad Road during the morning peak. King Fahad Road is the biggest of the three main north-south routes through the core of Riyadh city. It comprises no fewer than five lanes in each direction, which, according to the Highways

Capacity Manual (HCM), gives a notional capacity of more than 20,000 vehicles per hour. Figure 1.1 shows that, even with this extremely high capacity, provision is overwhelmed by the influx of morning commuters, and this pattern is repeated across the majority of arterial routes in the Riyadh City Core. Faced with conditions such as these, it's hardly surprising the Saudi Arabian government and Riyadh city authorities are looking for solutions.

Saudi Arabia represents an interesting microcosm of the intersection between transport and urban planning (Reza Farhani, 2013). Certain cities, including Riyadh itself, have very large populations, and an almost complete dominance of the private car, yet there is also a firm recognition that solutions are needed to the problems of urban sprawl and transport network efficiency (Reza Farhani, 2013). Although most of the Ministry of Transport's work still focuses on maintaining and building freeways (Al-Dubikhi, 2007), that paradigm is changing. This represents a shift in the continuous 50-year development of Riyadh's transport infrastructure.

In 2003, this paradigm shift became particularly apparent when the Council of Ministers authorised the Ministry of Transport to carry out comprehensive public transport studies, not only in Riyadh, but across all Saudi cities, regardless of their size. These transit studies mark a significant departure in transportation policy from a continued dependency on automobiles (Al-Dubikhi, 2007). The outcomes of these studies mean the introduction of public transport is being considered as a way of reducing traffic congestion and meeting the city's future travel requirements (ADA, 1999, 2003, 2004).

In Riyadh, this includes a showcase project, the Riyadh Metro, which is the world's most expensive metro project, in which the government itself is heavily invested both financially and reputationally. This project is covered in detail in Chapter 3, and forms a major part of this thesis. It is thus an exciting time for transportation research in Riyadh.

1.1.1 Total car dominance

A particular feature of Riyadh is the tremendous growth in automobile dependence, which makes the city's transport system unique (Aljoufi, 2012). Almost all people permitted to drive in Riyadh have access to a private vehicle, and approximately 95-97% of journeys are made by car (Altwaijri, 2012). Between 1968 and 1996, the total number of automobiles in use increased from 26,880 to an estimated 670,300 (Al-Mosaind, 2001). Average vehicle ownership per household also increased nearly two and a half times during the same period (Al-Dubikhi, 2007). These figures can be compared with other capital cities. In London and Paris, for example, the percentage of journeys made by car more than 40% (metropolitanojubilee, 2013; Paris by train, 2016). Indeed, the emerging phenomenon in many cities (London and Paris included) is that of 'peak car'.

'Peak car' refers to car miles per person per year reaching a peak and showing indications of decline, something transport planning did not conceive of previously (Hobbs and Harriss, 2013). Estimating future trends in traffic is important because infrastructure development, land use and environmental and climate change policy require long-term planning. The assumption for many decades, particularly in Riyadh, was that car use would continue to grow. Peak car seems to represent a point along a city's growth trajectory wherein the assumptions of continuing car use, and expansion of the road network, have reached their limits.

Riyadh is in many ways unique. The strong Islamic culture and conventions regarding privacy explain a large part of the current reliance on cars, and these factors continue to exert an influence on the development of the transport system (as fully described in Chapter 2 and 3). Traveller needs concerning privacy manifest can be seen in the way people prefer to drive alone rather than travel with others, and there are conventions around how women in particular travel (with many opting to travel with male relatives). This combines with the often severe climatic conditions (in which summer temperatures regularly reach 55°C), to make the comfort of a private air conditioned car clear.

The underlying reasons for this phenomenon are explored as part of this research, with particular reference to issues around policy transfer and local culture.

1.1.2 A critical juncture

From the images of overcrowded roads shown in Figure 1.1, the idea of peak car, and the arrival of the Riyadh Metro, it is clear Riyadh stands at a critical juncture. A conference on public transport held in Riyadh in October 2000 marked this. Here, local/national bodies and officials met transport and planning experts to review the situation. This conference helped give attention to the need to establish policies that would help plan the way forward. Arising from the outcomes of the conference, Arriyadh Development Authority (ADA) devised a public transport pilot study to provide guidance on how new public transport initiatives could be used to better meet future growth in travel demand.

Most cities have developed their public transport systems in parallel with general urban growth, so that systems and services have evolved with the city. In the words of the ADA, *“This is not so in Riyadh, and thus this initiative represents a unique opportunity to introduce a modern public transport system to a developed urban area that is, by any measure, without recognisable public transport,”* (ADA, 2015). It is not a simple matter to construct a large-scale public transport infrastructure and then expect people to switch travel modes.

Indeed, it is a major challenge to persuade car users to transfer to public transport. In most other cities, the main issue is one of car users changing transport modes when the public transport ‘offer’ is comparable in time and comfort with private car use, and is generally perceived as attractive and comfortable for the whole journey. This is the basis for most conventional transport mode choices. In Riyadh, there are the added complications of an extreme climate and Islamic culture, and both factors are powerful in favouring the status quo.

The challenge, therefore, is to change Saudis' attitudes towards the use of public transport as an everyday experience. This is unlikely to be achieved in a short period of time (A. Abdullah, 2011). Changing people's attitudes and then their travel behaviour has to be a gradual process as users become both comfortable about using the new services and confident that they will perform as reliably as a private car at all times (A. Abdullah, 2011). A particular challenge in Riyadh and across the Middle-East more generally is that public transport must offer the privacy and other culturally-guided norms travellers need and expect (Al Dubaiki, 2007). Norms that the private car supports.

A tram system such as the one recently constructed in Edinburgh, which has a completely open layout that all users can access freely, with limited seating and high interior/external visibility, would not be deemed appropriate in Saudi Arabia. A small example of further issues can be seen in the results of a recent travel survey completed by King Saud University (University of Riyadh) (Mubarak, 2004). Respondents claimed they faced traffic every day, and that they are not using public transportation because it is not comfortable (in terms of accessibility, efficiency and reliability, see Chapter 2). They also have an alternative in the form of their own private cars.

Equally, they said that if transportation in the city of Riyadh was widely suitable, they would use it to reduce traffic as much as possible. Those who did use public transport said that the transport authorities must focus on developing transportation such as underground subways, useful transport means and luxury services (Mubarak, 2004). Even here, though, there is further complexity in that what travellers say they want is not always the same as how they will actually behave if those 'wants' are provided (see Sections 2.3 and 2.6).

So Riyadh stands at a critical juncture, and it has already made some large-scale decisions about the future direction it wishes to take. As of 2015, the city is investing in a new metro system in the hope and expectation that it will dramatically alleviate the traffic conditions shown so graphically in Figure 1.1, and help improve transport performance in the future. To put this in context, USD 22.5 billion is currently the

single largest investment in public transport made by any city in the world (ADA, 2015).

The Riyadh Metro is part of the Riyadh Public Transport Project (RPTP), which includes the construction of a metro network, a bus system and other transport services in Riyadh (ADA, 2015). According to the ADA, the metro network is set to constitute the backbone of Riyadh's public transport system. The flowing table 1.1 highlights on the metro feature and specification according to (ADA, 2015).

Table 1.1 summarize of Riyadh metro feature and specifications (Source; ADA, 2015)

Feature	Description
Design and specifications	<ul style="list-style-type: none"> • The latest technologies were implemented to the metro network design. • Driverless and control rooms will operate and observe the metro network. • Metro cars are semi-attached with different classes to ensure more flexibility.
Stations	<ul style="list-style-type: none"> • Air-conditioned and information system with Wi-Fi access. • Using solar cells technology to save about 20% of the power required for air-conditioning and lightening. • Located in highly populated areas and at the intersections of metro lines and bus network. • Parking lots, ticket outlets, shops, and customer service offices are included.
Safety and comfort	<ul style="list-style-type: none"> • Surveillance cameras, early warning systems, fire fighting systems, tunnel safety systems and a communication system that supports real-time communication with competent security authorities.
Fleet parking and maintenance centers	<ul style="list-style-type: none"> • Seven parking & maintenance centers, • Offices for the staff and parking areas for the metro train fleet
Power source	<ul style="list-style-type: none"> • 12 main power plants to feed the project will be built from scratch for that reason generating 468 MVA.
Design and financial contract	<ul style="list-style-type: none"> • The BACS consortium includes Bechtel, Almabani General Contractors, Consolidated Contractors Company, Siemens Aktiengesellschaft and AECOM. • The Arriyadh New Mobility (ANM) consortium includes Bombardier, Ansaldo STS, Impregilo SPA, Larsen & Toubro Limited, Nesma & Partners, Hyder Consulting, IDOM and Worley Parsons Arabia. • FAST consortium includes FCC Construction SA, Samsung C&T Corporation, Alstom Transport, Strukton Civiël, Freyssinet Saudi Arabia, Tecnica Y Proyectos and SETEC.

Contract period	<ul style="list-style-type: none"> • The construction has been launched on 3rd April 2014 for 48 months plus 8 months to prepare the sites and 4 months experimental operation.
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Moreover, the metro service with six lines, a total length of 176km and +85 stations will cover most of the densely populated areas, public facilities and the educational, commercial and medical institutions based across the city. The network will also be connected to King Khalid International Airport and King Abdullah Financial District, the main universities and the central area as shown in figure 1.2 below:

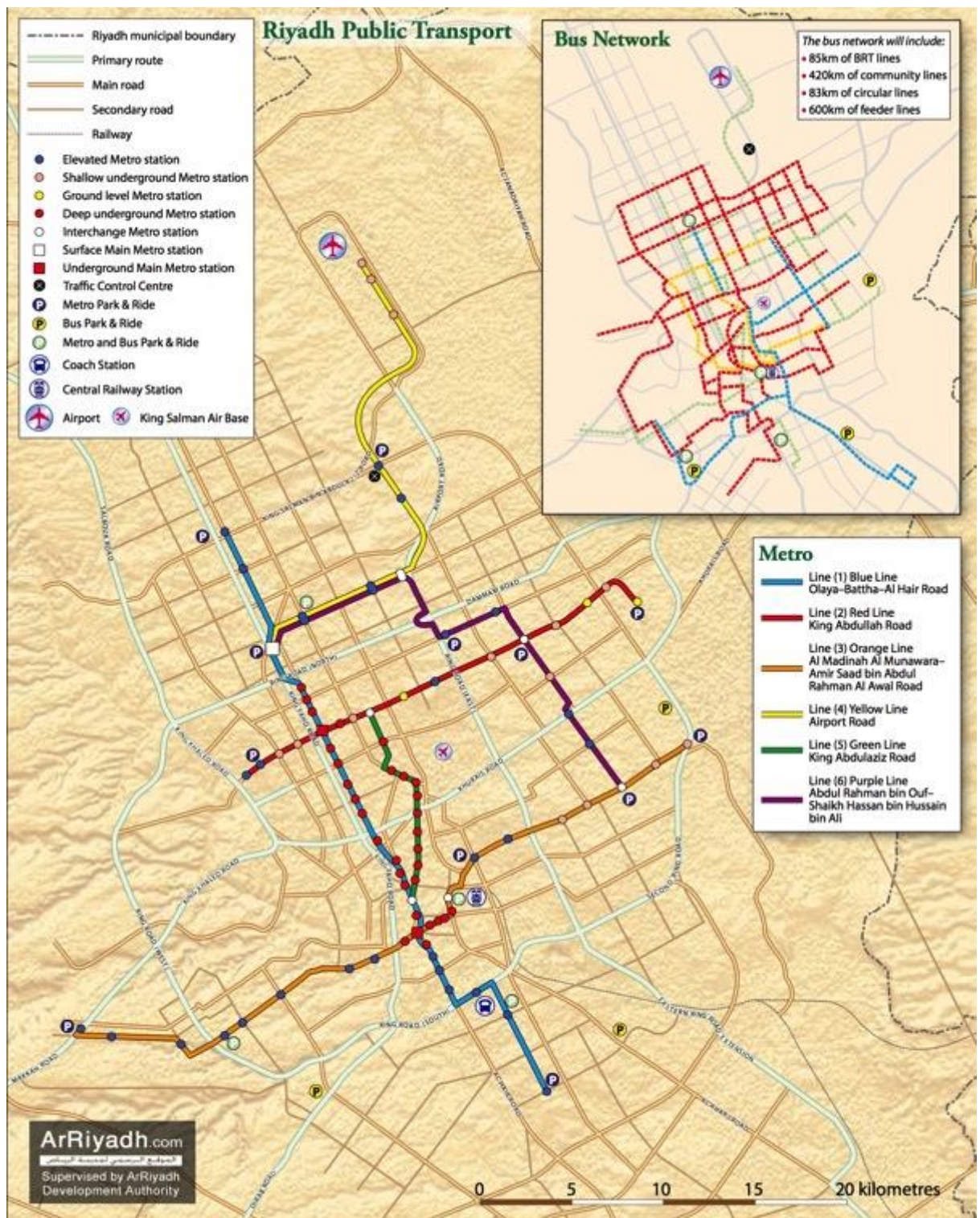


Figure 1.2 Main routes of Riyadh's metro network (ADA, 2015)

1.1.3 Early warnings

The Riyadh Metro is state-of-the-art and draws heavily on international best practice. According to the ADA itself: *"The latest technologies were incorporated into the metro network design. The trains will run automatically (without a driver). Central control rooms will be used to operate and monitor trains with high degree of accuracy. The metro car specifications include the world's latest technologies. The cars can be divided inside to accommodate different service classes in addition to the family class."* (ADA, 2015). Despite this, there is a critically important issue this thesis sets out to explore. It can be stated simply as follows:

Just because the metro system has proven ‘successful’ in other countries does not guarantee a similar ‘success’ in Riyadh?

This question is of central importance, given experience of previous ‘bought in’ solutions which fell substantially short of expectations despite representing ‘best practice’ in other continents and regions. This issue strikes to the heart of the policy transfer debate, a concept that it will be considered in depth during this research (as fully described in Chapter 3).

The Riyadh Metro itself is unique, but the process of investing heavily in a ‘best-practice’ solution from elsewhere is not (See Chapter 3). Previous initiatives reveal some of the pitfalls of this approach. Los Angeles’ metro ridership represents 10.6% of the population, far less than the 43% predicted (Los Angeles Metropolitan Transportation Authority, 2016). Similarly, Kuala Lumpur’s metro, inspired by similar systems in London, Paris and Stuttgart, has a ridership of just 16%, not the 43% predicted (Kevin Smith, 2016).

There is a discernible trend in Saudi Arabia to ‘buy in’ ‘off-the-shelf’ solutions from other societies, yet clearly there is a risk that these solutions will fail to meet

expectations when they come in contact with the unique Saudi Arabian socio-economic and cultural contexts. For example, women currently constitute less than 9% of all public transport users due to the lack of regard for female privacy, and their desire to travel separately from men to whom they are not related (see Section 2.6). Early indications suggest the current metro project may also be at risk of policy transfer issues.

The Riyadh Metro, like all similar projects, is not just about providing infrastructure, but also about influencing peoples' travel behaviour. This is a complex area. Adding to the complexity and, equally, perhaps to the risks of the Riyadh Metro not meeting expectations is that the ADA will, at the same time as launching the Riyadh Metro project, expand and enhance the road network. This, in turn, shows a process of integration between all components of the transport network and its sustainability (see Figure 1.3). Again, a fully integrated transport system is a complex business, and, if worldwide experience serves as a guide, is rarely achieved.

On the ground, ADA has commissioned an independent, international engineering company (Royal Haskoning DHV) to provide a range of consultancy and project management services. The consultancy team analysed the city's transport system during a two-year period between 2012 and 2014. According to ADA, they identified a range of issues varying from traffic jam problems, congested areas of congested parts, and poorly functioning traffic signals, to traffic safety and behavioural problems. This team is documenting these, together with plans, pictures and videos, analysis results, proposed solutions, implementation requirements. This helps to provide a wide range of raw data for this thesis. What is very clear is that the Saudi government and the ADA are taking implementation of a large-scale metro project, and the attendant behavioral changes seriously. (Chapters 3 and 4 provide more details). The research presented in this thesis builds on and extends this analysis.

As already noted, the Riyadh Metro scheme is not an isolated piece of infrastructure to be implemented as a standalone project. It will form a part of an integrated transport system. This, in turn, makes the problem more complex, because not only are there more factors to consider, but those factors interact in ways that are often surprising and

difficult to predict. Riyadh already has experience of projects that have been unsuccessful due to policy transfer issues (as described in Section 3.2).

This thesis aims to make a key contribution to the debate by shedding new light on this complexity, and for this, issues of culture and policy transfer will form the underlying theoretical backdrop. Policy transfer will be covered in more detail in Chapter 3, but it can be briefly defined here as follows: *“A process in which knowledge about policies, administrative arrangements, institutions, etc. in one time and/or place is used in the development of policies, administrative arrangements and institutions in another time and/or place”* (Dolowitz & Marsh, 2000).

There are various other definitions of policy transfer, but most share the idea that it is a process of using knowledge about policy-making from one setting and applying it to another (Marsdena and Steadb, 2012). Irrespective of which definition is chosen, most commentators agree that issues arising from policy transfer are becoming more prevalent (see, for example, Evans, 2009; Common, 2001). As a theoretical backdrop, policy transfer provides a highly valid and useful lens through which to project the transport issues and problems as they relate to Riyadh.

1.2 Transportation and the development of cities

At first glance, the provision of transport in cities should be fairly straightforward. Methods exist to predict future demand, and the engineering knowledge exists to design (and build) infrastructure to meet that demand. This is often how previous transport investment in cities has been argued: firstly on the basis of how to allocate growth, and subsequently on the main means of promoting economic development and the revitalisation of depressed areas (Banister, 1994). Purely engineering-based evidence often conflicts with economic and behavioural evidence.

Quite often, the addition of new road links means that more traffic will be generated, making the environment more polluted and increasing mobility problems for those

without access to cars (Leeming et al, 1969). This is referred to as the ‘induced demand’ effect, and is one of many second, third and greater order effects stemming from the inherent complexity involved in transport planning. Wegener (2009) writes that urban land use and transport are closely inter-linked. The need for travel and goods transport is mainly created by spatial separation of human activities. The suburbanisation of cities, for example, is connected with spatial division of retail, services and manufacturing, and hence with increasing mobility.

According to Cullingworth (2006), housing and employment has often tended to migrate out of the city, as is the case in Riyadh, along with shopping centres, science and industrial parks and leisure facilities. Green field sites are attractive because the densities of development are much lower and the disadvantages of city centres (e.g. congestion, high property prices and rents etc.) are absent. One side effect, of course, is that access to these new green field sites is usually made by car. The net result, particularly apparent in Riyadh, has been an unprecedented growth in car-based travel, with longer journey lengths.

There are examples of cities in which the transport infrastructure arrives ahead of development. Putrajaya in Malaysia is one current example, although outer suburban areas in cities as diverse as Glasgow and London also exhibited this feature between the 1900s and 1930s. It is far more common, however, for the opposite to be the case. Typically, transport infrastructure expands more slowly than the city itself. Detroit is perhaps the most graphic example of this (Thomson, 1978). The very infrastructure responsible for Detroit’s growth (its urban and inter-urban freeway network) was the same infrastructure which enabled the population to leave the inner city for more attractive suburban areas (Thomson, 1978).

In Riyadh, the development of local centres of activity within the expanded city, with a particular concentration of functions such as dedicated financial, retail and other centres, is particularly noticeable. While this form of zoning has an intuitive appeal, it is still the case that *“the relations and links between urban development and transport are not well known even in the physical sense”* (Banister, 2006). Adding to the physical

proximity of similar economic activities are factors such as population density, rent, land prices, social factors such as equity and distributional factors, and environmental factors including quality of life. In all cases, transport has an important effect. It enables centres of economic activity to form, but, equally, it also allows them to disperse.

1.3 Problem statement

Urban transportation systems are complex entities incorporating many factors (Wang, Lu and Peng, 2008). According to Jörnson (2005), a complex system is usually made up of several interacting elements with non-linear interactions and bifurcation points which may result in a multitude of outcomes and creative and surprising responses (Jörnson, 2005). Any urban transport arrangement can be considered a complex system, and the word 'complex' may be interpreted in different ways, with the complexity (however it is defined) varying from city to city (Jörnson, 2005).

Understanding this complexity has become very important if unexpected outcomes are to be avoided. In Riyadh, the proximal 'problem' (or symptom), one that all transport users can observe, is congestion. Congestion has become part of daily life in many areas of Riyadh. This has numerous negative effects, including foregone productivity, reduced quality of life and atmospheric contamination (Farahani et al., 2013). The direct consequences of this for transport users include frequently lengthy delays on the city's main routes. As discussed above, these factors are symptoms of bigger processes such as population growth, which drives increases in land values, urban migration and urban sprawl. The latter is responsible for changes in the spatial structure of cities (Yang and Lo, 2003). This, in turn, creates transport issues including traffic congestion in the city and rapid growth (Harvey and Clark, 1965).

It is clear that transportation is a highly complex problem. This complexity stems from the evolution of cities from the dense urban fabric of medieval settlements, where most of daily mobility was on foot, into vast modern metropolitan areas with their massive volumes of intraregional traffic. As a worldwide phenomenon, this would not have been

possible without improving first the railway and later the private automobile. Riyadh represents a particularly rapid case study of precisely this process (see Chapter 2).

Wenger's Land-use feedback cycle. (2009; Figure 1.3) hints at the structure of this complexity. The model has 14 key factors linked in a circular fashion, each preceding factor serving as an input to the one before. Within the model, there are several important feedback/feed forward loops. For example, transport factors such as ownership, mode choice and travel costs occupy half of the cycle and are reflected in the other half, which include land-use factors such as attractiveness, location decision for investors, construction, location decision for users etc. Accessibility and activities sit at the 'equator' or junction of the model and are 'connector factors' between the transport and land-use feedback cycles.

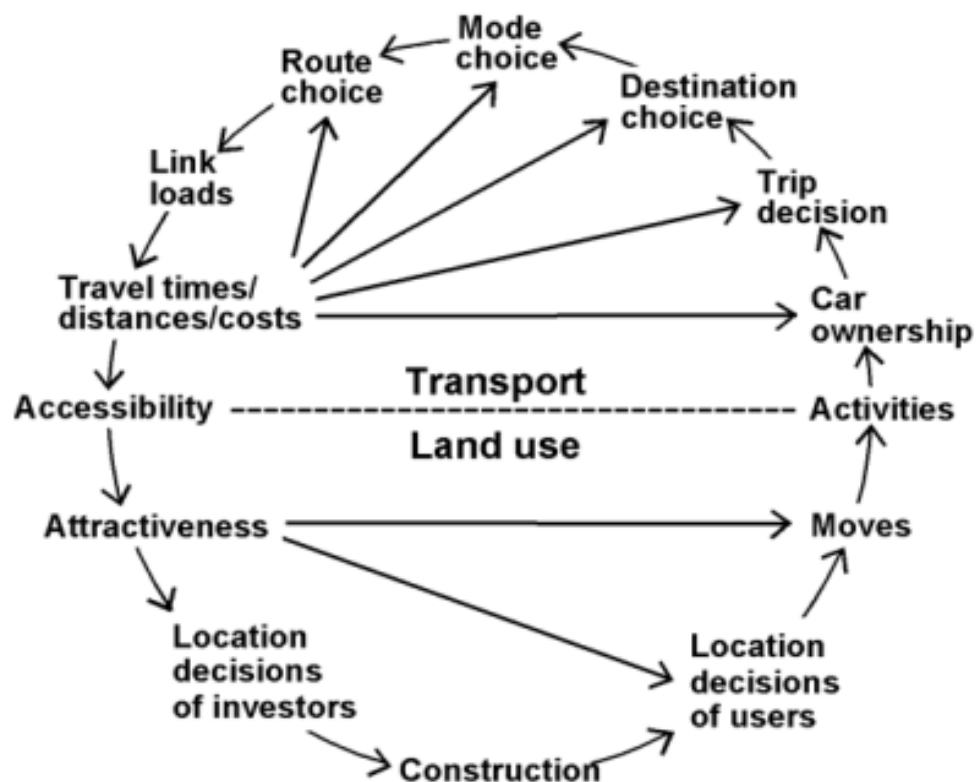


Figure 1.3 Transport and land use cycle (M, Wenger, 2009)

Riyadh reflects the transport and land use model well. It is a fast-growing city with a car-dominated transport system that cannot grow further without significant

disadvantages for the health and well-being of the city. This situation has arisen because of a range of wider issues, some unique to Riyadh and others that are universal. They can be stated as follows:

1.3.1 Key Issue 1: Population growth and finite capacity

There is finite available capacity for growth, particularly in the inner areas of the city, for the expansion of the highway infrastructure to continue to meet mobility expectations an expansion of car use and ownership. This has significant implications for land use and transportation systems. In view of growing car ownership and currently high automobile dependency in Riyadh, maintaining adequate mobility in a reliable, safe and sustainable manner has become a dominant challenge. It is evident that a continuation of the present trends will lead to a serious negative impact in both economic and environmental terms (Farhani, 2013).

According to current trends, by 2030 the resident population will increase to more than 15 million people (ADA, 2015). The ADA recognised that increased population, increased economic activity, increased personal expectations and increased population growth all contribute to increased mobility demands and thus to increases in travel demand. The existing road networks cannot successfully absorb these very significant increases in demand. The main transport corridors into the city are already heavily used at peak periods, and this is incompatible with sustainable economic growth to meet higher mobility expectations for a future urban population of 15 million by 2030 without a significant change in mode use. A robust public transport option is a logical component of the transport planning strategies but not without risk, as outlined in Chapters 4, 6 and 7.

1.3.2 Key Issue 2: Investment in a metro system

The General Speaker of the Ministry of Transport in Saudi Arabia, Abdullah Allohaidan, told Agency France Press AFP - a global news agency based in France - in

a recent interview that *“The rail and bus development — whose construction is changing the face of Riyadh — is the largest such project underway in the Middle East, and I think in the whole world.”* (AFP, 2016). He added: *“Three foreign consortia are building the metro, with France’s Alstom, Canada’s Bombardier and Germany’s Siemens among the major participants. The city’s existing public transportation system includes beaten-up minibuses carrying immigrant workers,”* (AFP, 2016).

The ADA has undertaken various studies on the city’s developmental needs through the ongoing Metropolitan Development Strategy for Riyadh (MEDSTAR) project. MEDSTAR addresses Riyadh’s strategic planning needs, and recognises that the success of the expected planning outcomes will depend on having a coherent strategy that supports urban mobility. High quality public transport is an important element of the mobility strategy, one that contributes to maintaining Riyadh’s economic prosperity. It follows that there is a need to identify a public transport system that’s appropriate for this large, culturally unique city (Al-Dubikhi, 2007). An ambitious metro system has been chosen and is covered in detail within Chapters 4, 6 and 7.

1.3.3 Key Issue 3: Culture and context

Society, demography and culture are all unique in Riyadh, and will continue to play a central role in the development of the city’s transport networks. One defining feature is that women in Saudi Arabia are not permitted to drive (currently), and therefore rely on male relatives, foreign male private drivers and taxis, resulting in large numbers of trips per Saudi household.

In Saudi Arabia, men and women are always segregated (due to Islamic and social norms) on urban buses, and usually travel separately on group transportation services. Because of this tradition, females expect a door-to-door service which public transport, generally, is ill-equipped to provide (Alfozan, 2011). Culture and context exert a significant influence on other travel habits in Riyadh. Males aged 18 and over (the legal driving age) make considerably more trips than females of a similar age.

According to Al-Dubikhi (2007), there is a concern over this significant difference despite today's social conditions on female travel, and higher female participation rates in employment and education. The ADA claims that the number of trips made by women may have been under-reported. Al-Dubikhi added: *"Based on the most recent estimates, the ADA states that 'Saudi households generate a large number of trips, partially to meet the needs of the female members who are usually reliant on male household drivers,'* (Al-Dubikhi, 2007). For cultural and social reasons, women are unlikely to be allowed to drive in Saudi Arabia for the foreseeable future, leaving the entire family highly dependent on adult males for travel (Al-Dubikhi, 2007).

This interesting facet of national culture clearly has a significant effect on transport system use and the type of future transport system that will elicit the needed (and hoped for) behavioural change. There is also a prominent demographic aspect to Riyadh's transport needs. Half of the city's population is under the age of 18, and hence below the legal driving age. In the very near future, they will grow up, and this is likely to result in increasing car numbers. This is yet another demographic issue expected to lead to more daily trips. Underpinning all of these, is a continuing rise in Riyadh's population generally (Al-Dubikhi, 2007).

1.3.4 Tackling the key issues

There are many ways in which these key issues could be tackled, some of which are more satisfactory than others. It would be possible to adopt a purely transport engineering perspective, but this would be likely to downplay issues of culture and context, focusing instead on the actual infrastructure. Similarly, it would be possible to take a strictly social science approach and concentrate on culture and context, but run the risk of downplaying the challenges of engineering a system to meet these needs.

What is needed, therefore, is an interdisciplinary approach which aims to tackle both aspects. An interdisciplinary approach is highly consistent with the complex human and technical aspects of the problems at hand, and requires that the key issues above should be set to define the research strategy or 'themes' which can provide the necessary

insights. These strategic, tactical and operational aspects of the research are described in the next section, which deals with the research aims, objectives and specific questions, before proceeding to the research methodology.

1.4 Specific research aims, objectives and questions

The unique challenges of rapidly growing cities such as Riyadh create a need to firstly understand how transport policies transfer between cultures, and, secondly, on a more practical level, the innovative means of visualising and modelling the complexities of future transport scenarios. The results will inform our understanding of how complex urban planning factors such as land use, population density and road networks interact, while challenging long-held assumptions about the conditions under which certain transport solutions will deliver their intended results.

To achieve these aims, the research has a set of themes and objectives and a series of defined research questions. The research themes are a direct response to the key issues shown above. These include policy transfer, urban expansion and Riyadh's transport future scenarios.

These themes enable the key issues to be integrated within an interdisciplinary research framework, and are shown in the first column of Table 1.2. Six objectives, have been set out and are shown in the second column of Table 1.2. The themes and objectives give rise to a set of specific research questions that the following chapters will attempt to answer (shown in the third column of Table 1.2). The fourth column of Table 1.2 shows the chapters within the thesis which the related research question is answered.

Table 1.2 Overall research themes, objectives and questions

Stage 1: <u>Contextual backdrop</u>			
Theme	Objective	Question	Answered in Chapter
Policy transfer, urban expansion	<u>To understand the range of factors which have contributed to Riyadh's current traffic situation, and to analyse the causes of this problem.</u>	1) What are the main aspects of transportation that contribute to Riyadh's current traffic situation, which is almost 100% dependent on private car use?	Chapter 2
		2) What are the stages of development that contributed to the current form of Riyadh's road network?	
		3) What are the current transport issues in Riyadh?	
	To understand the origins of Riyadh's transport planning policies, and their effects over the last five decades.	4) Of all the possible configurations and transport policies Riyadh could have chosen, why these policies specifically?	Chapter 3
		5) In what way is the theoretical framework of policy transfer evident in Riyadh?	
		6) Is there a risk that policy transfer issues could arise with new 'bought in' projects such as the Riyadh Metro?	
Stage 2: <u>Qualitative analysis</u>			
Riyadh future scenarios	To generate and validate future transport scenarios with key Riyadh stakeholders.	7) Where do Riyadh's traffic problems come from?	Chapter 4
		8) How are policy transfer issues evident in current decision making?	
		9) What expectations do key stakeholders have for current and future transport projects?	

Stage 3: <u>Quantitative analysis</u>			
<u>Riyadh future scenarios</u>	<u>To create and calibrate a Strategic Microsimulation Model (SMM) for the most congested part of the Riyadh City Core.</u>	10) Can microsimulation be used as a valid approach to transport planning in Riyadh, and can a model of Riyadh’s city core be created?	Chapter 5
		11) How can the microsimulation model of Riyadh’s city core be used to reveal the structure and character of Riyadh’s existing transport challenges?	
		12) Can such models enable larger-scale policy interventions to be explored, visualised and communicated effectively to stakeholders?	
	Create Overall Performance Curves (OPCs) that characterise Riyadh’s road network performance, and compare them to predictions from the future scenarios.	13) To what extent can microsimulation model diagnostics shed light on future Riyadh traffic scenarios?	Chapter 6
14) What does the Riyadh transport situation look like under all possible conditions?			
Stage 4: <u>Studying the impact of future scenario</u>			
<u>Policy transfer, urban expansion, Riyadh future scenarios</u>	To investigate the performance of future scenarios when implemented in the SMM.	15) To what extent can the extracted future strategies address Riyadh’s traffic problems, and could they be successful when used separately or combined?	Chapter 7
		16) In what way are policy transfer issues manifest in the microsimulation results, and do they challenge existing assumptions?	

1.5 Research structure and methodology:

The research's high-level structure is governed by the three themes shown and described in Table 1.2. These include policy transfer, urban expansion and Riyadh's transport future. Table 1.2 can also be represented diagrammatically to communicate these themes, and to generate a high-level description of the thesis's overall structure. The following Figure 1.4 illustrates the stages and processes within the thesis.

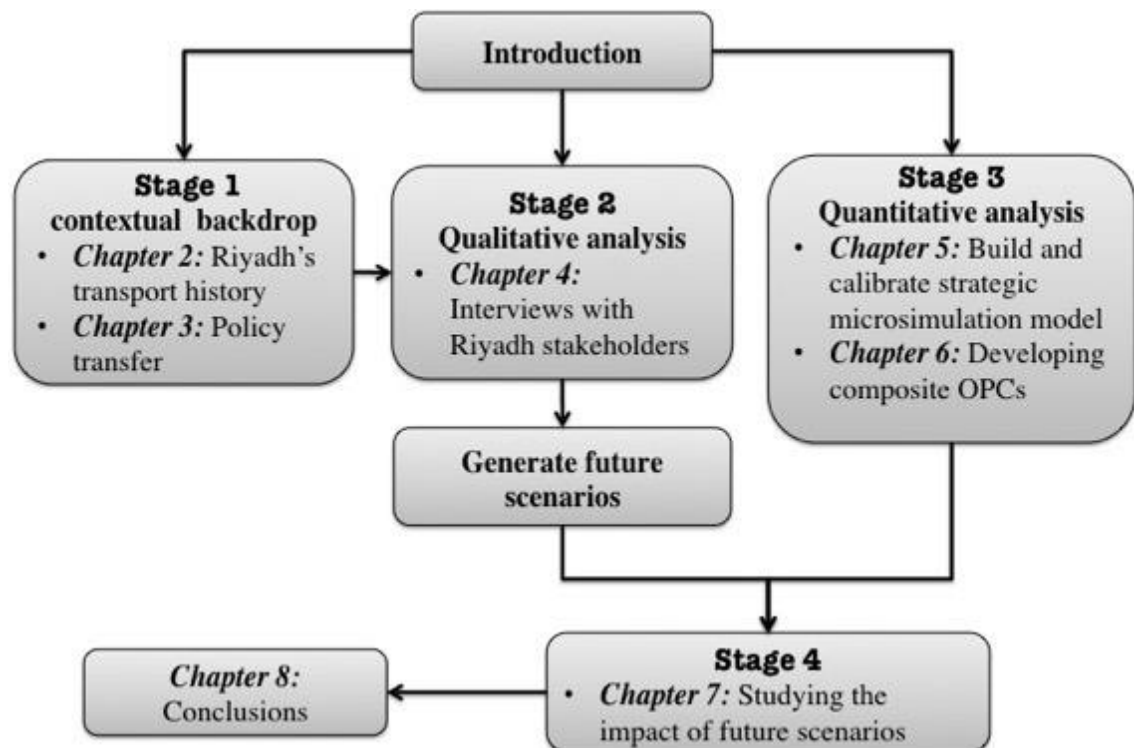


Figure 1.4 Study design intersections over the thesis (author; original)

As seen in Figure 1.4, there are three parallel ways leading to Stage 4 and the assessment of future transport scenarios. Stages 1 and 2 will provide the thesis with its theoretical approach. Stage 3 will use microsimulation modelling as a novel tool for testing future scenarios. Then Stage 4 will combine all stages to investigate the efficiency of future scenarios within the same test bed. The following section discusses each of these four stages in detail.

1.6 Research methodology

The research incorporates a mixed-method approach. The qualitative side will support the research through interviews with decision makers (as detailed in Chapter 4), as well as using policy transfer concepts and mapping them to Riyadh (Chapters 2, 3 and 4). A quantitative approach will support the research via the construction and calibration of an agent-based traffic microsimulation model (Chapters 5 and 6) as a way of testing future transport scenarios (Chapter 7). The methodological and theoretical specifics are dealt with in the respective chapters. The following section describes the broad research methodology and is divided into three parts: qualitative analysis, quantitative analysis and a mixed approach.

1.6.1 Qualitative analysis

Qualitative analysis is a securities analysis that uses subjective judgement based on unquantifiable information (investopedia, 2017). This high-level approach serves the thesis by exploring the key issues of Riyadh's transport history, current situation and the main aspects of policy transfer in Riyadh. Previous policy transfer successes and failures will be reviewed and qualitative insights extracted. Supporting data for the qualitative analyses was collected through a comprehensive search and synthesis of the previous literature, along with access to all master plans for Riyadh since the 1970s and their attendant data.

Semi-structured interviews (see Chapter 4) have been performed with key Riyadh transport stakeholders. These interviews were aimed at eliciting the views of stakeholders, urban planners and transport policymakers in relation to current strategies. The qualitative outputs of these interviews serve as inputs to the design of future scenarios for testing and evaluation. The qualitative interview data was distinctive because of its quality, standard and its ability to elicit the required information for analysis. Specifically, access to these key stakeholders is not normally granted, and this step helps to give the research unusual levels of validity.

1.6.2 Quantitative analysis

The qualitative methods provide inputs to the quantitative methods. Quantitative analysis refers to economic, business or financial analysis that aims to understand or predict behaviour or events through the use of mathematical measurements and calculations or statistics (investopedia, 2017). The main quantitative tool used in this research is a Strategic Microsimulation Model (SMM) for the Riyadh city core.

Microsimulation is a new, increasingly popular transport planning method. It takes an Agent-Based Modelling (ABM) approach, which involves creating computer models of real road networks and their traffic. Setting the initial conditions for these ABMs required the qualitative data collected earlier.

A microsimulation approach was adopted because it's highly consistent with the theoretical/methodological perspective of the thesis. It's particularly appropriate to multidisciplinary transport studies, understanding how a range of interconnected factors interact, and in understanding how outcomes (both expected and unexpected) can arise given a set of particular input conditions. Microsimulation is also particularly new to Riyadh. It has enabled the research to:

- Simulate real-world traffic in Riyadh
- Include 3D real-time imagery, so that policy transfer effects can be visualised and interpreted
- Include all vehicles in one simulation - private vehicles, buses and trams interact in the same model
- Assess the impact of the proposed Riyadh Metro
- Assess the impact of a range of other future scenarios

1.6.3 State-of-the-art [mixed approach]

As shown in Figure 1.4, this research was carried out in three parallel stages. Stages 1 and 2 represent the theoretical/qualitative arm of the research that led to the generation of future scenarios. Stage 3 is the technical/quantitative arm of the research. During this stage, the microsimulation model was deployed as a strategic tool to measure the impact of each scenario.

The adopted approach is a highly novel one. The behaviour of the Riyadh city core transport network was measured on key variables under all conditions, from free-flow to complete saturation. The key indicators were: level of service, traffic flow, travel time and queue length.

At each point between free-flow and saturation, the value of these indicators was extracted from the microsimulation and plotted into an Overall Performance Curve (OPC). These characterise the network under all possible conditions against which any scenario can be compared. In essence, the values of the model outputs for each scenario will be logged where X = traffic volume percentage against the current situation and Y = the indicator value (e.g. travel time, queue length etc.). The composite OPCs is therefore a graphical representation showing the impacts of future scenarios on Riyadh's road network in comparison with the current status.

It enables alternative scenarios to be tested, for example; what if the Metro is more successful than expected? Or indeed less successful? Eventualities such as these can similarly be plotted into the OPC curves to answer a range of questions such as: what is the minimum metro ridership needed to meet stakeholder expectations? If policy transfer issues are important, how sensitive are they to network performance? Are there points at which further modal shifts yield diminishing returns? And so on.

1.7 Chapter summary

The following section summarises what each chapter of this thesis will cover, and how each one contributes to each of the main research stages (shown in Table 1.1 and Figure 1.4), and what specific research questions it will seek to answer.

Stage 1: contextual backdrop

Chapter 1 is the introduction to the thesis, and includes the problem statement, research objectives and research methodology. In Chapter 2, the research investigates the main aspects of transport and urban planning that have contributed to Riyadh's traffic current situation of almost 100% private car use. The research then moves on to Chapter 3. This chapter focuses on and analyses the following key issues: the problem of 'bought in' solutions, policy transfer issues, and urban transport policies and their implementation in Arab countries, with a particular focus on those in the Arabian Gulf.

Stage 2: qualitative analysis

In Chapter 4, the research has privileged access to key stakeholders in the Riyadh transportation sector, from government-level decision makers to practising transportation professionals. This access offers an understanding, in a very direct way, of: a) what the policy picture is in Riyadh, b) how policy transfer issues are manifest in current decision making, and c) the expectations that key stakeholders have for current and future projects. These interviews then contribute to the development of future scenarios for testing in the SMM.

The author met several policy and decision makers, with each interviewee accurately chosen according to specific criteria, including: occupation, their decision influence, and their departments responsibilities. These insights help to provide high levels of external validity for the thesis, meaning research end users will recognise the scenarios to be tested.

Stage 3: quantitative analysis

Chapter 5 presents the design, development and calibration of the strategic microsimulation model for Riyadh city core SMM. This model serves as the experimental platform for testing key aspects of urban planning theory and resulting in practical solutions for the most congested parts of Riyadh's city core. The study area is 7.4 kilometres (km) long from south to north, and 1.3km wide from east to west. The study area lies adjacent to Olaya, the district next to Olaya Street and King Fahd Road. The model simulates approximately 40,000 trips over a two-hour period between 06:30 am and 08:30 am.

The model was created through nine steps as follows: 1) Identification, 2) Data collection, 3) Coding, 4) Error checking, 5) Model creation, 6) Calibration 7) Testing of alternatives, 8) Documentation, and 9) Presentation. These steps involved close liaison with the developers of the microsimulation package (SIAS Ltd) and took more than 12 months to construct and calibrate to real-world traffic conditions. The model was also formally audited by the software developers, a step routinely applied to commercial models (see appendix c).

Stage 4: studying the impact of future scenarios

As described in Section 1.6.3, the research moves on to use the model as a strategic tool to examine future scenarios. From Stage 3 onwards, the research generated four indicators from the SMM to measure the conditions on the road network. These indicators are: a) Level of service, b) Traffic flow, c) journey time and d) Queue length. These indicators were taken from the current situation on Riyadh's road network at a specific time and volume of traffic flow according to real network data (as described in Section 1.6.2).

Following calibration to current traffic conditions, the research then reran the SMM under all conditions of traffic flow, starting from an empty network until it was fully

saturated. This was achieved by incrementally increasing the volumes expressed in the model's underlying Origin/Destination (O/D) matrix. The values of the respective network indicators (LoS, travel time, queue length etc.) were logged and these, in turn, served as coordinates for the composite OPCs. The composite OPCs is the final product of the modelling stage, serving the thesis as a test bed for all future transport scenarios (see Chapter 6).

Having developed composite OPCs for all indicators, it was then time to drop the future scenarios forecast onto the OPCs to study the impact of each one extracted from Stages 1 and 2. In other words, whatever the scenario expectations, they will be somewhere on the composite OPCs. In addition, the research will go on to review international best practice/facts of each scenario to help determine how realistic each scenario is under the policy transfer conditions as they apply to Riyadh.

Thus, the research will put actual numerical estimates onto the earlier policy predictions and scenarios, these estimates come from international best practice through two parameters: Parameter 1) policy transfer, Policy transfer, Parameter 2) policy implementation. Both of these parameters leads to three hypotheses: Hypothesis 1) Policy transfer and policy implementation both are a success, Hypothesis 2) Policy transfer or policy implementation (one of these factors) is failed; in other words, it is the 'mid-point' prediction. Hypothesis 3) Policy transfer and policy implementation are both failed.

From this analysis, a comparison table for Riyadh's future transport scenarios can be presented, positioning the Saudi capital among other worldwide cities and the success (or otherwise) they have had with similar transport interventions.

1.8 Contribution

1.8.1 Research gaps

There are four significant gaps in our current understanding, which this thesis aims to fill:

1. Riyadh is a unique, dynamic city, and the causes of its current transport problems are not fully understood.
2. The Riyadh Metro project is currently one of the largest projects of its kind anywhere in the world, and the problem of policy transfer must be taken into account: currently it is not.
3. While the concept of policy transfer is highly valid for Riyadh, there is considerable innovation available in the way its theoretical tenets can be visualised and subjected to a range of direct tests.
4. There is a range of possible solutions for Riyadh's congestion problems, but the extent to which they will meet expectations, and the extent to which these expectations might be challenged by emerging features of Riyadh's inherent policy transfer complexity, are not yet known.

1.8.2 Theory

The thesis makes a number of significant contributions to existing theory. These include a mapping of the existing policy transfer theory to the situation in Riyadh, and an extension of this existing theory to take account of Riyadh's unique sociocultural and climatic factors. These include: a) Economic aspects and a strong financial situation, b) Cultural and privacy elements which are at the heart of the Islamic world and c) Walking and the effects of the climate, which reaches 57 Celsius in the summer. The research will investigate these factors to understand the underlying issues which have led Riyadh to its current situation.

1.8.3 Method

The research deploys traffic microsimulation as a way of representing the most congested parts of Riyadh. Microsimulation is a new transport planning method which is becoming increasingly popular. This research evaluates microsimulation as an approach to transport planning, the development of a microsimulation model of a transport corridor in Riyadh, its calibration to live traffic situations, and how it can be used to reveal the structure and character of Riyadh's existing transport challenges. This research considers the role of such models in enabling larger-scale policy interventions to be explored, visualised and communicated effectively to stakeholders.

1.8.4 Practice

Simulation programmes are often used to imitate a small-scale neighbourhood, corridor or even an individual road. Their use as a strategic tool is far less common; their use in a policy transfer context is unique. The congestion mitigation solutions available to planners and other stakeholders are numerous, and their effectiveness varies from one culture to another. Solutions cannot be proven effective in any society unless they are tested and implemented. This research sets out a range of practical methods and insights which engineers, city planners, transport system stakeholders, decision makers and beneficiaries can all use.

CHAPTER 2 Riyadh “From oasis to Metropolis”

2.1 Introduction

The city of Riyadh is the capital of the Kingdom of Saudi Arabia and the seat of government. It's located in the eastern part of the Arabian Peninsula at 600 metres above sea level in the heart of the desert, with no lakes or rivers. It is on the Najd plateau (Saudi Arabia's central area), which lies to the west of the Tuwaiq mountain range and east of the Dahna desert (see Figure 2.1). It's a city with a deep history and a former travel route for trade and pilgrimages between the Red Sea and the Arabian Gulf. Historically, Riyadh dates back to 1704, and it has played a dominant role in the history of the Najd region.

The name Riyadh means the rich place of gardens and orchards in Arabic. Riyadh was the main centre of the first and second Saudi states in which, before the current Kingdom of Saudi Arabia, small states belonged to the Al-Saud tribe.



Figure 2.1 Riyadh is located on the Najd plateau at an elevation of 600m in the central area of Saudi Arabia (Source: Google maps).

Today, Riyadh is a major international metropolis with population of eight million, luxury facilities and advanced services, and is the political, economic and cultural

centre of the Kingdom of Saudi Arabia, as well as its capital city. In Riyadh, there are many global, regional and private headquarters such as those of the Arab Human Rights Organization, Organization of the Petroleum Exporting Countries (OPEC) and international energy companies including Aramco, Petromin and Fuchs.

The intellectual and cultural background to the Kingdom of Saudi Arabia is firmly based on Arab and Islamic heritage, while consciously opening up to modern Western theories and data to benefit from these currents without being beholden to them (ADA, 2015). Saudi culture has its roots in its Islamic heritage (which calls for tolerance, moderation and respect for other cultures) and urges optimism and to confront crises with wisdom and rationality and the ability to make strong decisions. These decisions go through many channels in the Saudi government before finally being approved in a way that's consistent with the kingdom's vision (see Chapter 4).

Riyadh's road network is one of its main urban landmarks. It covers a wide geographical area, and has been designed to a high standard. These roads play an important role in determining the city's urban structure, and affect people's mobility behaviours from one place to another. Significant resources have been allocated over the past 50 years to create a modern, hierarchical road network across the city's urban development. Riyadh is unique for a range of specific transportation reasons. It is no exaggeration to say that it forms an unparalleled case study on which to bring to bear a wide range of contemporary transport issues, including policy transfer.

The purpose of this chapter, therefore, is to achieve research objective: **to understand the range of factors which have contributed to Riyadh's current traffic situation, and to analyse the causes of this problem.** Specifically, this chapter investigates the main transport factors that contributed to Riyadh's current traffic situation, which is almost 100% dependent on private car use. The key issues to be discussed and analysed include: existing road network patterns, current public transport services and car ownership issues.

2.2 Background

Riyadh has been a car-focused city since the 1950s, and the economic boom of the 1970s compounded this. The Saudi capital has witnessed tremendous growth in automobile dependency over the last few decades. According to Al-Mosaind (2001), between 1968 and 1996 the total number of automobiles in use increased from 26,880 to an estimated 670,300. Average vehicle ownership per household also increased nearly two and a half times during the same period (Al-Dubikhi, 2007). Since the start of this decade, Riyadh's planning authority has been giving serious consideration to providing an alternative to the private car and reducing automobile dependency, despite the fact that neither oil supply nor funding for extra roads are issues for the city (ADA, 1999, 2003).

Due to increasing car ownership, however, traffic congestion is becoming a serious problem, and the planning authority is considering introducing public transport as one way of reducing this congestion and meeting the city's future travel requirements (ADA, 1999, 2003, 2004). However, this is no simple matter. Riyadh's Islamic culture and conventions regarding privacy have had a profound effect on the development of its transport system, and will be explored in detail in this chapter. Before the discussion of these factors, the research now will explore the transport history in Riyadh since 1940s before the automobile era in the following section:

2.2.1 Old city

Riyadh's history, and its growth from a relatively small settlement into a great modern city, are inextricably linked with the rise of the Saudi state. With Riyadh as the capital of the Kingdom of Saudi Arabia, which Abdul Aziz bin Abdul Rahman Al Saud (Ibn Saud) founded, it was inevitable that the city would grow. By 1955, all ministries and government offices had been moved to or established in Riyadh. In the same year, a Royal Decree was issued raising the status of the municipality of Riyadh to that of a mayoralty (ADA, 2015).

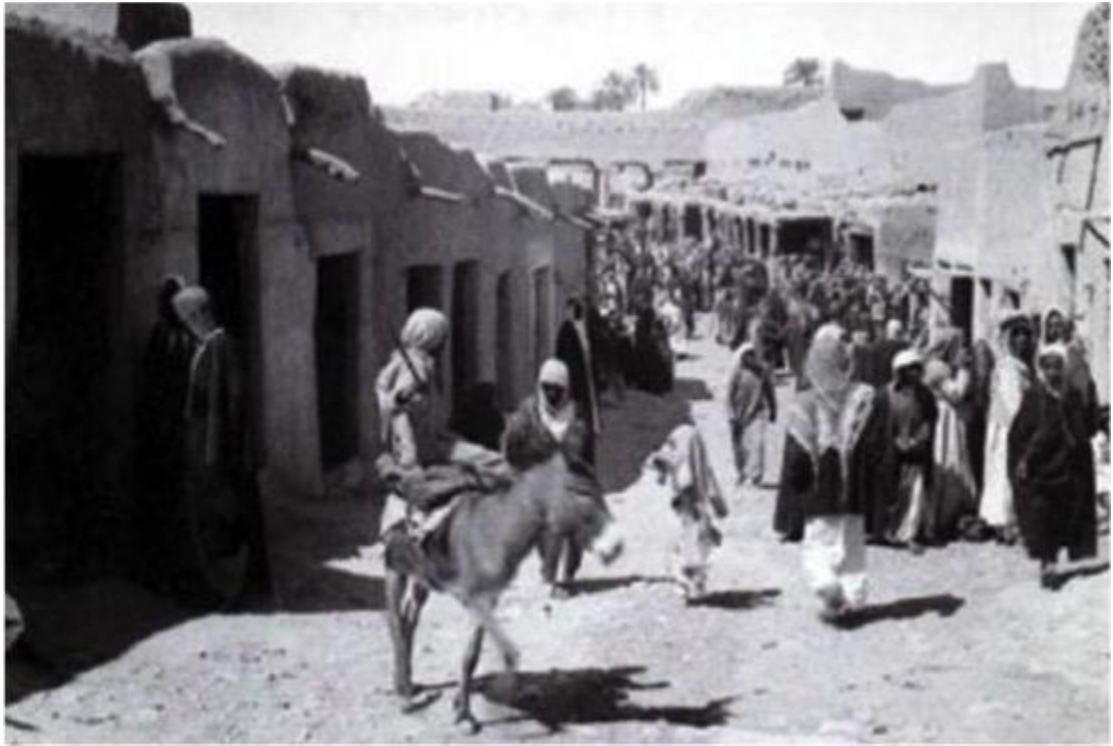


Figure 2.2 Riyadh during the 1940s before automobiles arrived (Source: ADA, 2015)

Travel in Riyadh before 1940 was by camel or horse (Figure 2.2). With the emergence of the motor vehicle in the 1940s, the first highway for automobiles was built in Riyadh, a paved stone road linking a second large palace and administrative complex two kilometres north of the existing city, Qasr Al-Murabba (king's palace) (Al-Hathloul, 2002). A British expert visited Saudi Arabia during 1950s and he sketched Riyadh and all the main features of the city as shown in Figure 2.3. The city at this time was surrounded by an ancient fortified wall with nine gates. A palace, fort and mosque were positioned within these walls and the main thoroughfare ran from Thumari Gate to Shomaisi Gate between Duhairi Gate and Dakimi Gate (MOT, 2016).

The first road to be converted/built for automobile use is shown in Figure 2.3, and ran from the main palace to the other palace through Budaiya Gate. Between the 1940s and the late 1950s, the major roads of the old town were widened to provide access for motor vehicles, despite the low car ownership at the time (Al-Hathloul, 2002). In the 1950s, oil had recently been discovered in Saudi Arabia, and the Saudi Arabian government and the United States agreed to establish the Saudi Arabian American Oil Company (Aramco) (saudiaramco, 2017).

At the same time, the first railway was constructed four kilometres east of the old city, and King Abdul Aziz inaugurated the first railway linking Riyadh and Dammam. The railway was an integral part of the Aramco initiative, and instrumental in moving oil products from inland locations to the coast for onward shipping, and it formed a direct link between the east coast (the oil source) and the seat of government (MOT, 2016).

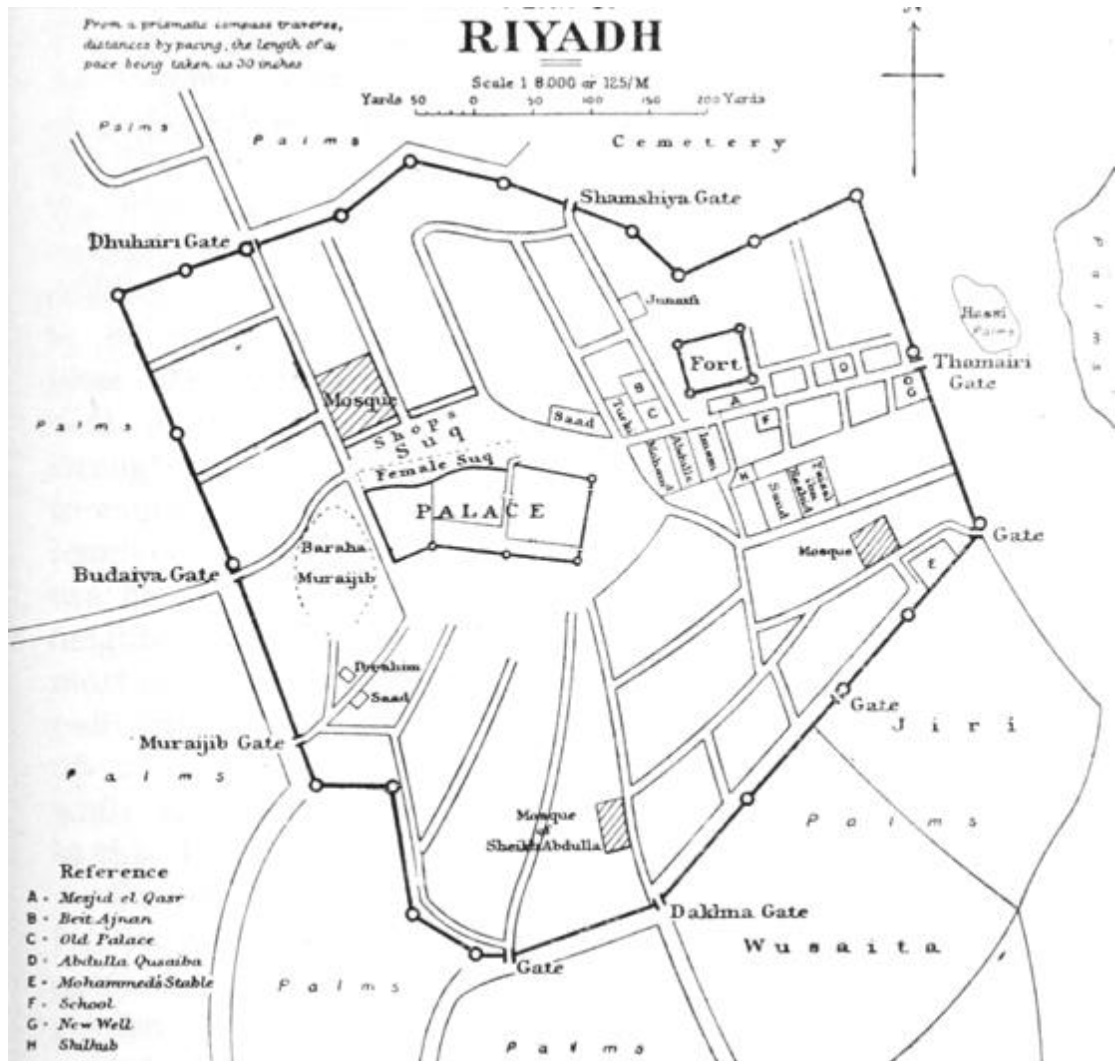


Figure 2.3 Old Riyadh landmarks, gates and streets sketched by Phliby, 1942

In 1951, the first airport was built seven kilometres north of the old city. It was established in conjunction with the establishment of the state airline Saudi Airlines (see Figure 2.4), (Al-Hathloul, 2002). The first plane to land in Saudi Arabia was a gift to King Abdul Aziz from American President Franklin D. Roosevelt in the early 1940s (MOT, 2016).



Figure 2.4 The first airplane landing in Saudi Arabia, early 1940s (Source: MOT, 2016)

According to Aramco (2017), the company began building schools in the 1950s, while encouraging the bringing of Saudi society into industrial sector and higher education in agreement with the Saudi government (saudiaramco, 2017). As the oil revolution began to benefit the Saudi economy, cars started to appear around the city. This in turn, then increased levels of vehicle ownership. During the ‘Aramco phase’, the kingdom experienced dramatic economic growth. These developments affected the city’s urban form, and were linked by a road network, increasing the city’s dependency on the private car. The city was transformed from a traditional pedestrian environment into an automobile-dependent city without the transition which most European cities experienced (Al-Hathloul, 2002).

2.2.2 Northern attraction

Doxiadis Associates, an international strategic planning consultancy firm based in Greece, was one of the first global strategic planning firms. Headquartered in Athens, the firm operated worldwide with offices in more than 12 countries. A review of Doxiadis Associates’ projects undertaken between 1955 and 1975 reveals numerous

master plans and urban design strategies for national capitals such as Washington D.C., Islamabad, Baghdad, Greater Khartoum, Riyadh and future expansion schemes for Stockholm and the Detroit region (Middleton, 2009). The Saudi government hired Doxiadis, and three official meetings took place at the firm's head office in Athens between July 28 and August 4 1969 to discuss the preliminary master plan. The Lord Mayor of Riyadh agreed the plan projected for development of the city towards the north-northwest, roughly parallel with Wadi Hanifa (Middleton, 2009).

One distinguishing feature of the Doxiadis plan was the extent to which it was adapted to the idea of the car, as shown in Figure 2.5. This adaptation was closely aligned with similar trends in the US and western Europe, where the primacy and dominance of the car were peaking (Middleton, 2009). In Riyadh, according to Doxiadis's master plan, activity spines were proposed, each to be serviced by mass freeways. There was a corresponding need to build more residential neighbourhoods and more activity centres, and so an overall increase in demand for travel had to be served more efficiently. This demand could only be served by private cars (Al-Dubikhi, 2007). Doxiadis designed the new city centre further to the north of the Old city because of the need to build more service buildings (ministries, government departments, etc.).

Doxiadis used the activity spine approach, as shown in Figure 2.5. In theory, the activity spines concept is one of several topological options and is opposed to the sub-centres concept (Al-Dubikhi, 2007). The sub-centres concept was not favoured because it was felt that freeway networks would encourage people to travel back and forth to district (or 'sub') centres instead of living within their boundaries as the later MEDSTAR plan proposed (Al-Dubikhi, 2007). That said, the activity spines concept has some similarities with the notion of 'strip development' and the elongation of travel patterns along corridors, and an attendant increase in trip lengths and car use. One interesting feature of the Doxiadis period was that Riyadh's citizens could buy a house on land in the new city under the availability of money during the oil boom. This, too, had a substantial effect on trip types and mode choices which is still felt today.

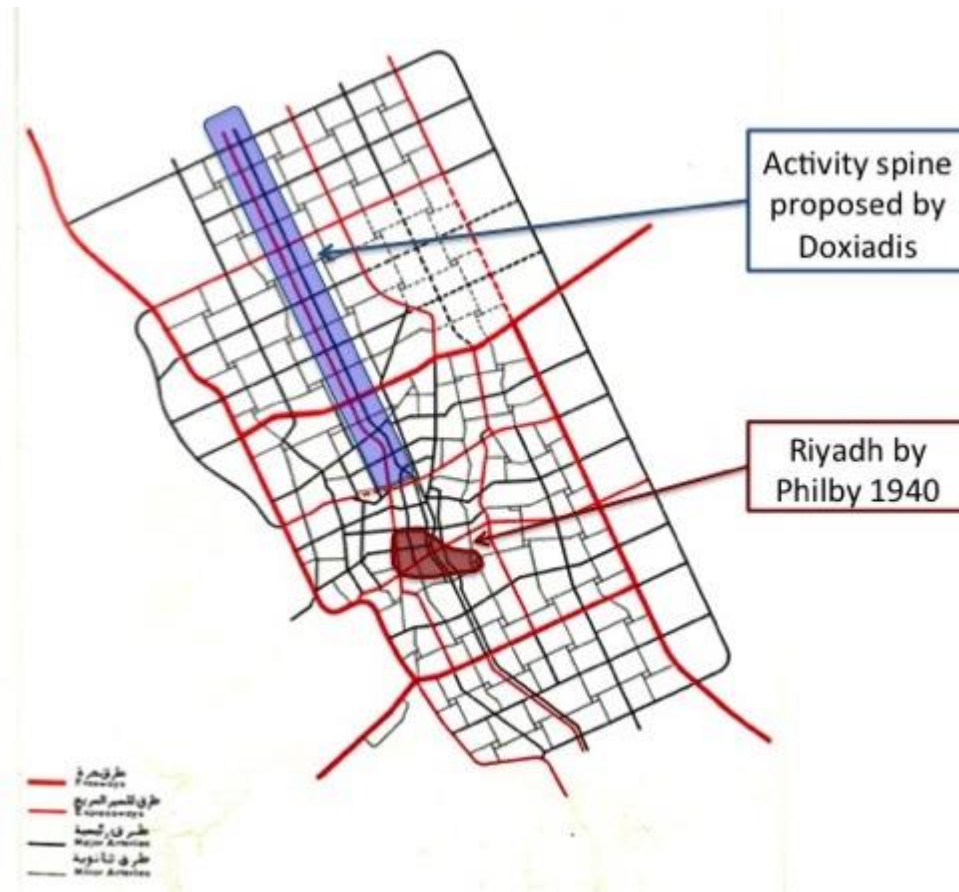


Figure 2.5 Doxiadis master plan for Riyadh, 1972 (Source: ADA, 2015, modified by author)

The built-up area of Riyadh in 1977 extended to 73 square kilometres, and the market demand for residential development outpaced supply as the implementation of the plan revealed the need for ongoing adjustments to the Doxiadis master plan. (Middleton, 2009). In fact, the plan was the main nucleus of Riyadh's urban structure during the city's journey of urbanisation, and the main roads are still expanding at the same direction of this plan, although the adjustments on the plans being after.

Then, SCET International a French consulting firm with expertise in urban infrastructure development, was hired to review and revise the Doxiadis master plan in late 1978. The SCET development plan focused on three modes of growth within the metropolitan area, the strategies for the provision of services in developed areas of the city as shown in Figure 2.6. Moreover, residential development was to occur to the north and north-east of the city (Middleton, 2009).

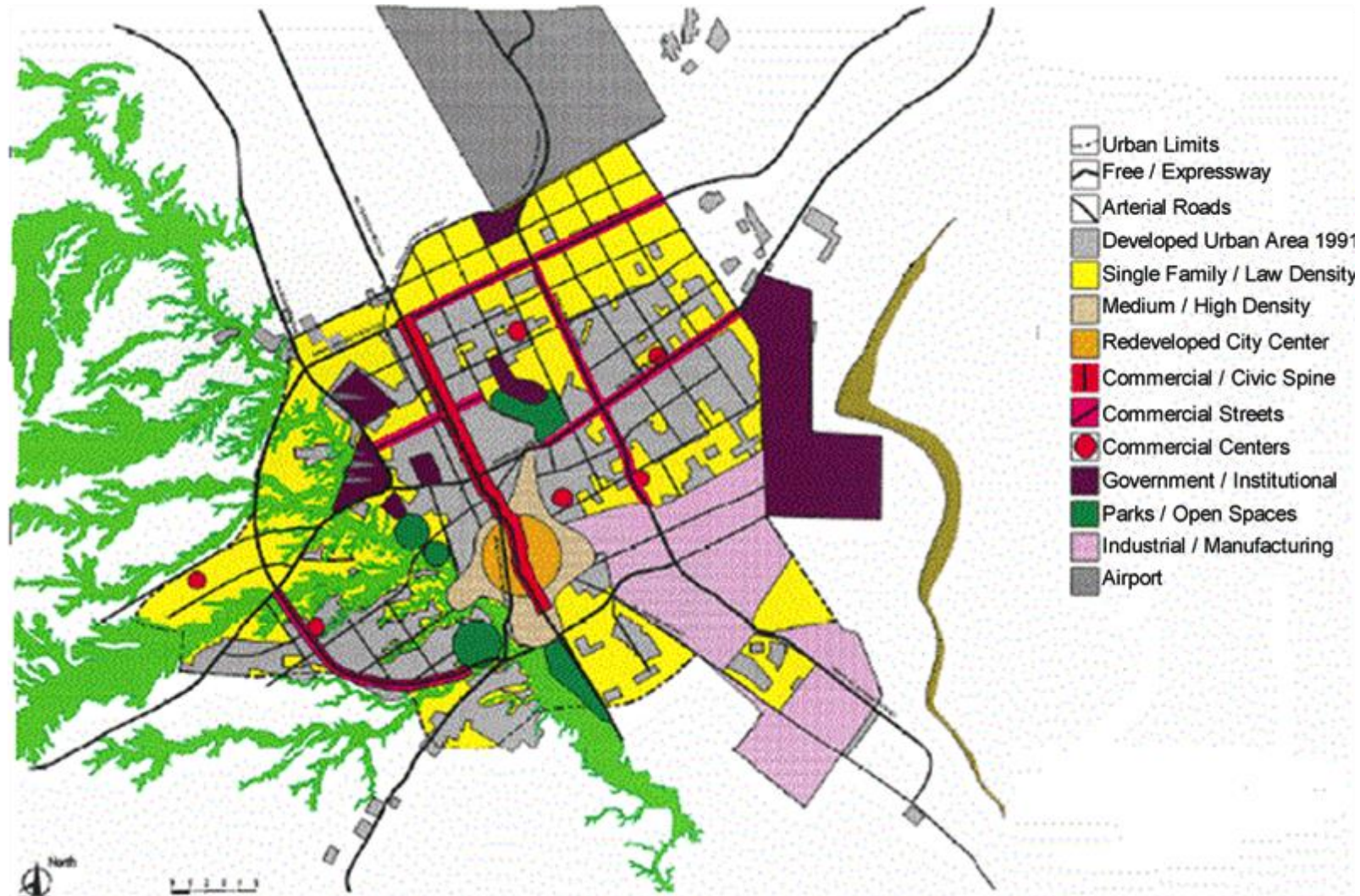


Figure 2.6 SCET 1978 revision to the Doxiadis master plan (source; ADA, 2015)

The Ministry of Municipal and Rural Affairs' moratorium on urban expansion policy instituted metropolitan outer boundary limits (Middleton, 2009). The most recent urban strategic framework for Riyadh, MEDSTAR, notes that extensive tracts of undeveloped land remain within the Urban Limits Phase 1 area as of 1996. However, Chapter 3 discusses Riyadh's development phases in terms of urban policy transfer and its impact on the Saudi capital (Middleton, 2009).

In summary, the story of Riyadh's journey from ancient walled town to modern twenty-first century city is in some respects a familiar one. What makes Riyadh stand out, however, is that rather than taking several centuries to reach this point, it has taken just 60 years. This accelerated growth and expansion represents a microcosm of city growth processes, making Riyadh an excellent case study. The following sections highlight particular topics explaining Riyadh's previous growth, as well as the challenges for the future. These include the issue of car ownership in Riyadh, the factors which affect mode choice and travel behaviour, and the specific factors making public transport in Riyadh unique. Overall, the following figure 2.7 illustrates the historical stages of Riyadh urban growth.

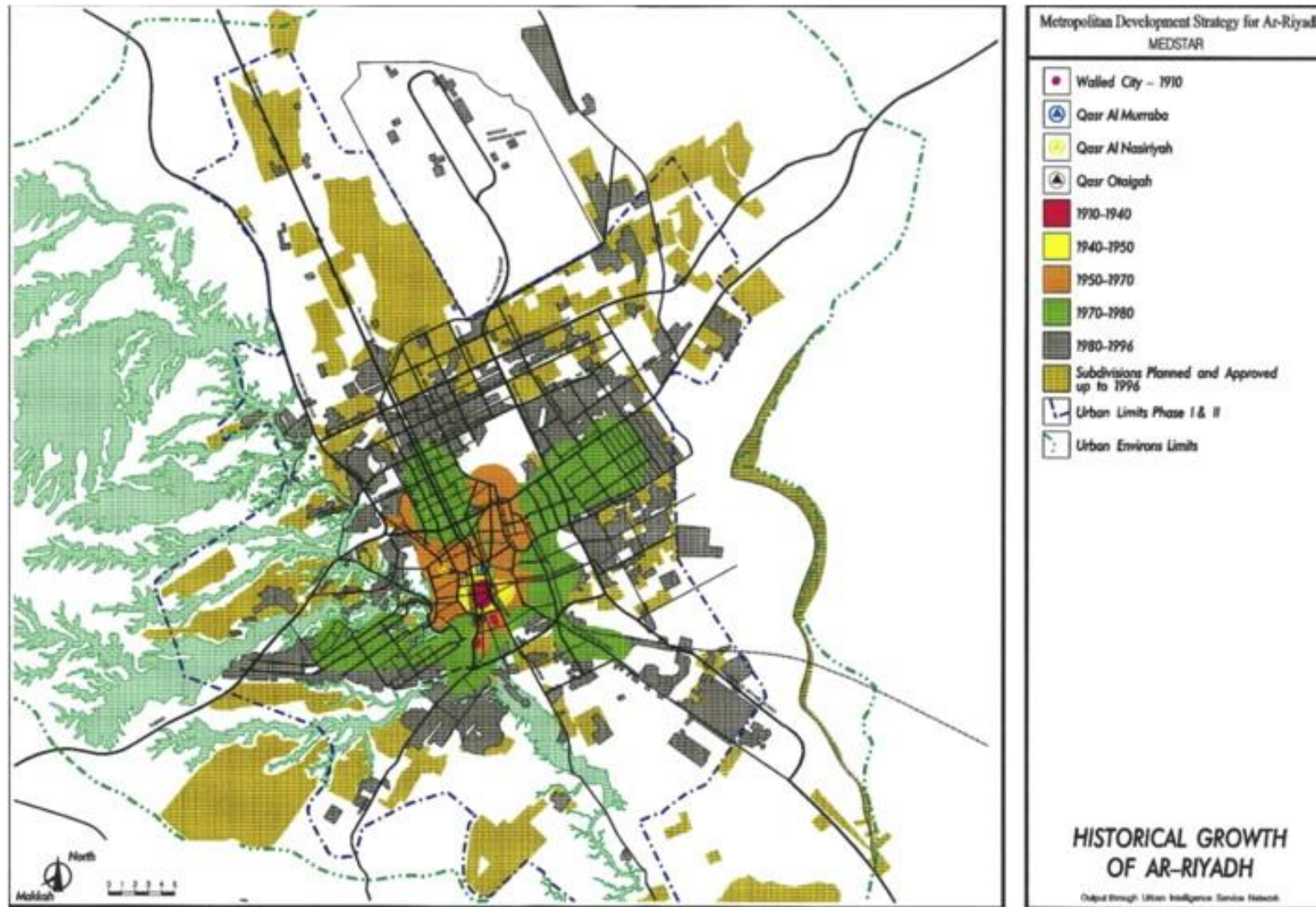


Figure 2.7 Historical Growth of Riyadh (Source; ADA, 2015)

2.3 Current Riyadh network characteristics

A rise in mobility has been linked to the growth in economic activity and population growth. This, alongside several other important structural and cultural factors, has generated high levels of car ownership and use. This, in turn, has led to the construction of a series of expressways and arterial roads across the city. However, the following figure shows the main road/transport links within the city:

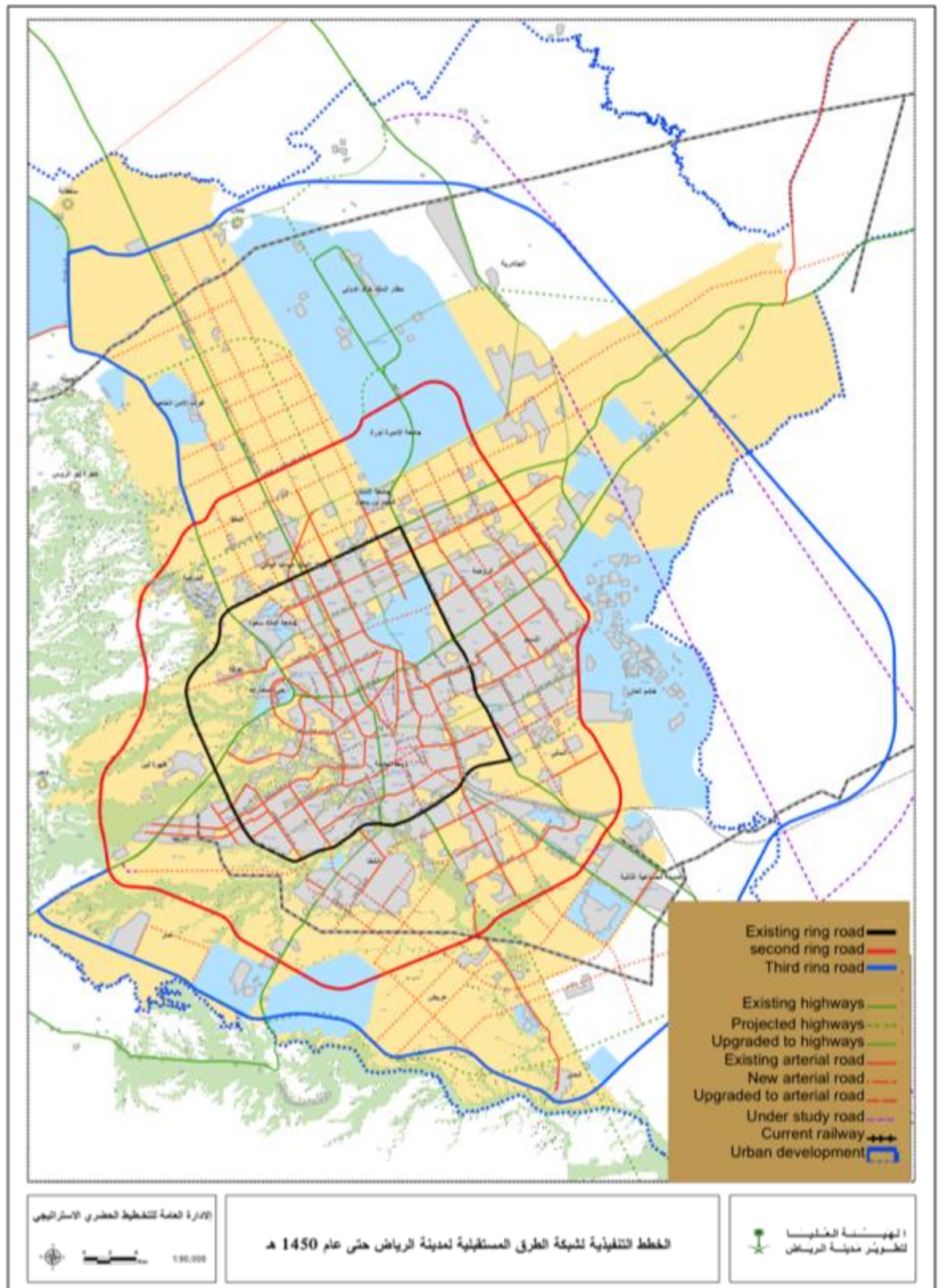


Figure 2.8 main road/transport links within the city (ADA, 2015)

2.3.1 Trip characteristics

As already mentioned, Riyadh has a huge road network that is constantly being developed. According to (ADA, 2015), home - work trips were the highest purposes, which were 32% of total trips. In addition, the highest occupancy rate of cars is home-school trips at a rate of 2.54 passenger per car and the lowest proportion was non-home, which were 19% of the total purpose of trips. The characteristics of this network, the purpose of trips and the occupancy rate are presented in the following table:

Table 2.1 trip characteristics of Riyadh networks (ADA, 2015)

Trip Purpose	Vehicle Occupancy	Percentage by Trip Purpose
Home- Work	1.52	32.02 %
Home- School	2.54	15.55 %
Home- Shop	1.76	8.58 %
Home-Other	1.55	24.86 %
Non-Home	1.39	19.00 %
Total	Average 1.68	100 %

2.3.2 Car ownership in Riyadh

In 1997, vehicle ownership rates per 1000 people were 224 (ADA, 2015), which is relatively low in comparison with other international cities. Major metropolitan cities in the US have an average of 604 cars per 1000 people, while Australia averages 491, Canada 524 and Europe 392 (Alfoazn, 2011). However, a defining feature of automobile use in Riyadh is its trajectory. KSA had no more than 22,805 cars in 1971, as shown in Figure 2.9. This number reached 2,052,934 cars in 1996 (Ministry of Interior (MOI), 1996). While not everyone has access to a private vehicle, cars are still affordable to many on a lower income, and this largely compensates for the lack of an effective public transport system (Alfoazn, 2011).

In the past, these have enabled high expectations of easy mobility to be met under the rubric of a dominant ‘predict and provide’ philosophy (Al-Dubikhi, 2007). This pattern of development is expected to prevail over the next two to three decades in the city.

According to the ADA estimates for 1968-2021 (Figure 2.8), both population and car ownership in Riyadh are expected to keep growing.

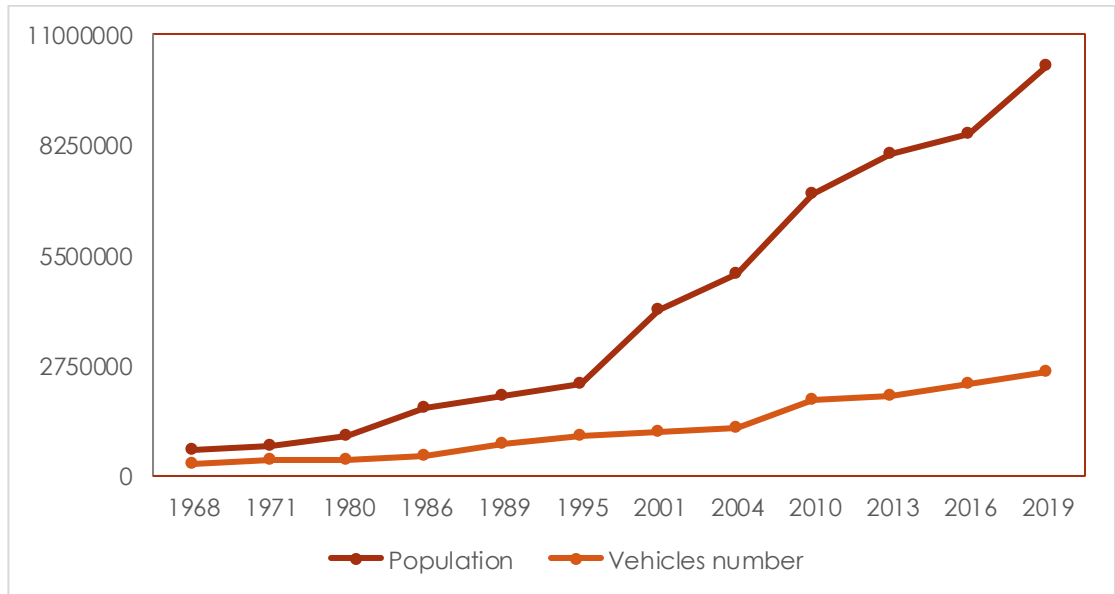


Figure 2.9 Population and car ownership in Riyadh 1968-2021 (source; ADA, 2015)

According to the Department of Statistics at the Saudi Ministry of Transport, private car use is expected to rise by 8% a year, which means Riyadh will reach additional 100% of private car use by 2029 if there is no other realistic mode of transport or future scenarios which help to reduce the growth in private car demand (MOT, 2016). The notion of 'Peak Car' (Gupta, 2014) reflects a situation in which the assumptions of continuing car use, and road network expansion, reach their limits (see Section 1.2).

'Peak Car' represents a distinct challenge to long-held assumptions in Riyadh, and has not previously been given serious consideration (Gupta, 2014). It's interesting to compare Saudi Arabia with other countries, for example China, where there are fewer than 50veh/1000 people, while in the US car ownership (during the 1980s) was approximately 700veh/1000 people including motorcycles (Gupta, 2014).

In Riyadh, meanwhile, that figure is currently 400veh/1000 person. The following Figure 2.10 shows vehicle ownership in a number of selected countries over the last six decades (Gupta, 2014).

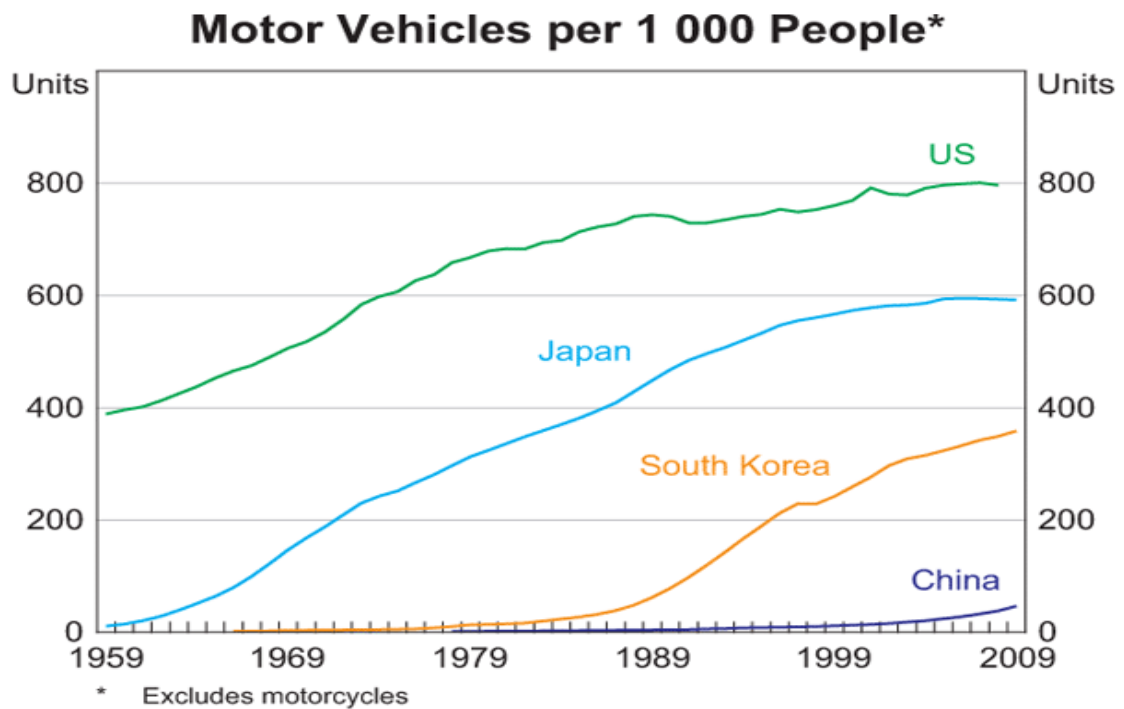


Figure 2.10 Ownership in selected countries during the last six decades (Source: Gupta, 2014)

The point at which ‘Peak Car’ is achieved varies depending on location. One interpretation of these figures is that Riyadh is well on its way towards ‘Peak Car’. In Riyadh, there is finite available capacity, even in a comparatively new city sited in a desert. The inner areas of the city are particularly limited in their ability to accommodate further expansion of the highway infrastructure. Meanwhile, high mobility expectations coupled with the continued growth in car use and ownership present significant implications for land use and transportation systems. Riyadh, therefore, is a microcosm of the challenges which many cities experience.

In view of the city’s growing car ownership and automobile dependency, maintaining adequate mobility reliably, safely and sustainably has become a key challenge. It is clear that, if current trends continue, there could be serious negative economic and environmental implications. Based on present trends, the available studies forecast that by 2030 the resident population could increase to more than 15 million, but the road capacity needed to maintain existing levels of service on the road network make this unsustainable. In the following sections, the research will explore the causal factors leading to Riyadh’s persistent increase in private car ownership, the effects in terms of congestion, and public transport’s potential future role.

2.4 Causal factors leading to an increase in private car ownership

2.4.1 North American patterns of urban development

According to Cervero (2005), Saudi cities resemble American patterns of urban development and transportation more closely than those of western Europe. Many cities, especially in North America, have decentralised homes and jobs, leading to a growth in suburb-to-suburb commuting and a corresponding shift from public transportation to the car (Cervero, 2005). Cities in the US are known for their ‘strip development’ and activity spines of the sort brought about by the Doxiadis plan (Middleton, 2009). Other cities in developing oil-producing countries have experienced a similar trend, with most of them not having fully formed public transport systems in place before the introduction of automobiles. Riyadh can be seen as a classic example of an urban environment designed solely around a car-based infrastructure.

In contrast with Riyadh and most American cities, where urban transport policy is still focused on the private car, many cities in Europe have managed to provide viable public transport options, even for the suburb-to-suburb commuter (Vuchic, 2005). This is because most European cities used public transport systems before there were cars. This developmental timeline could be important if public transport options are to be applied ‘out of sequence’ (i.e. after the arrival of the car), as in Riyadh’s case. This developmental sequence also brings to the fore issues of how policies and best practice in Europe, for example, might transfer to a context such as Riyadh’s (see Chapter 3).

2.4.2 Cheap petrol

A major factor in Riyadh’s car dominance is that petrol is cheap. At the time of writing, a litre of petrol in Saudi Arabia costs USD 0.2 compared with USD 1.45 in the UK and USD 0.62 in the US. Fuel prices, therefore, are not the barrier in Saudi Arabia that they might be elsewhere. This is because Saudi Arabia is one of the world’s largest oil-producing nations (Pengonda, 2014).

There are two direct side effects to this. The first is that the city's oil boom (from the 1960s onwards) made millions of dollars available to the government to invest in continued development. The expansion of much-needed services was apparent in governmental decrees from Saudi Arabian royalty (Mubarak, 2004), and it is from such decrees that master plans like Doxiadis's came into being.

The second side effect is cheap fuel. For many years, petrol prices in the Kingdom of Saudi Arabia have been the cheapest in the Gulf and among the lowest in the world. Only the most recent cuts in subsidies bring Saudi Arabia in line with most of its neighbours, whose fuel prices are still considerably cheaper than those of western Europe, America and eastern Asia.

At the beginning of 2016, Saudi Arabia increased the price of petrol by two-thirds to 0.75 riyals (USD 0.2) per litre, and from 0.45 riyals (USD 0.12) for 91-octane (Laodme.com, 2016). According to Figure 2.10, this is 72% lower than the next lowest-priced nation (the US), and a substantial 60% cheaper than fuel prices in the UK. What this means is that the social dimension for providing public transport is often more important than some issues that receive more attention in western cities, such as fuel costs. Put simply – and uniquely for Riyadh – the supply of cheap fuel is not an issue (Al-Dubikhi, 2007).

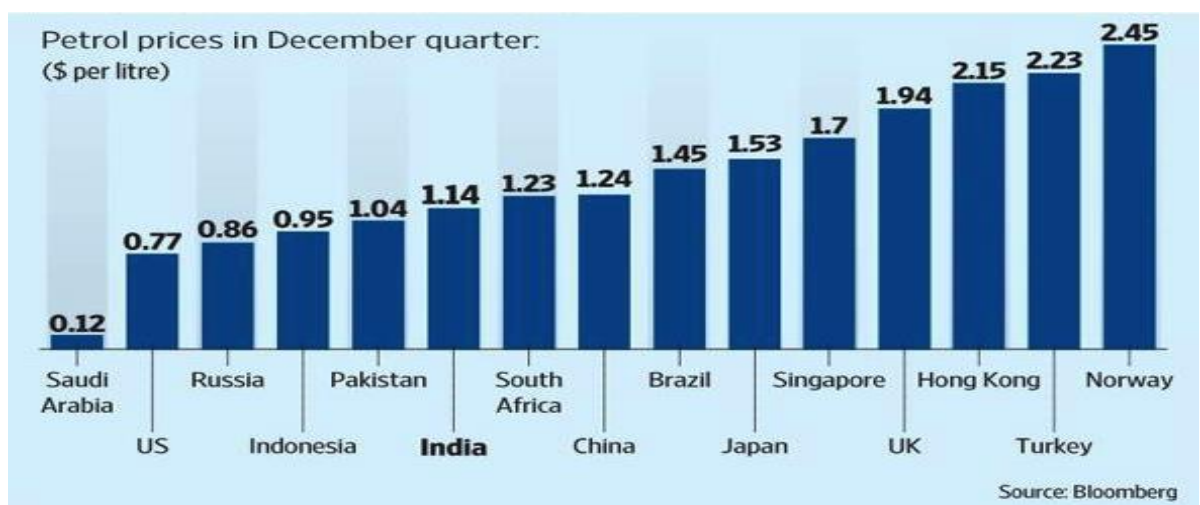


Figure 2.11 Comparison of petrol prices worldwide (source; Pengonda, 2014)

2.4.3 Economic and demographical aspects

According to Alfoazn (2011), there are four factors affecting future growth in car ownership in Riyadh: 1) The age profile, since a significantly higher than average proportion of the population is below driving age, 2) The average household size is large at 6.1 people, 3) The fact that women (due to cultural norms in Saudi Arabia) and a proportion of the expatriate workforce (due to licencing requirements) are not allowed to drive, and 4) Some of the ownership rates for international cities may include total vehicle fleets rather than just those vehicles which are available to households (thus artificially deflating the total for Riyadh).

In the future, according to the Riyadh Development Authority (ADA, 2015), the rate of vehicle ownership could increase as a result of changes in all these factors, in particular the age structure of the population, household formation, wealth and urban sprawl. This will be as a key issue for Riyadh, and will have an impact on the success or otherwise of policy interventions aimed at solving these problems (policy transfer will be covered in detail in Chapter 3).

Another significant reason why Riyadh is a car-based city is that people with access to cars simply never use public transport. The availability of private cars and their low running costs contribute strongly to this. For example, by global standards, car taxation in KSA is negligible: the registration charge is just SAR 250 (USD 66.7). Upper, middle and even working class Saudi residents tell visitors that public transport is for foreign workers or those travelling by employer-paid transport only (Al-Dubikhi, 2007). Where a private car is not available, many residents prefer to use a taxi instead of public transport. Riyadh is following, indeed amplifying, the Western or North American example in terms of automobile dependency. The expression many people have built their way of life around their cars is absolutely true of Riyadh (Al-Dubikhi, 2007).

In terms of the economic aspects, Saudi Arabia has experienced continued growth, which has attracted internal and external migration, mainly from people travelling into or within the country to work. A third of the city's population consists of expatriates

with fixed-term contracts, a large proportion of whom, due to their temporary status, are not allowed to drive (Al-Dubikhi, 2007). Because of the nature of their employment contracts and conditions, these workers have to travel in private buses or trucks (and their employers usually provide this transport).

However, as younger Saudis have begun to join the workforce, a national movement referred to as 'Saudisation' has become widespread over the past decade (Al-Dubikhi, 2007). This refers to a national strategy encouraged by the Saudi government to address unemployment and replace foreign labour with Saudi workers by supporting the private sector. This may reduce dependence on economic immigrants, particularly in management and professional positions. This means that itinerant foreign workers who are not permitted to drive will be replaced by Saudi nationals who are, so travel behaviour will change and the number of daily trips will increase (Al-Dubikhi, 2007).

2.4.4 Active travel and the effects of the climate

Riyadh's climate is extremely hot in summer and cold in winter, and characterised by low humidity throughout the year, especially in the summer. Equally, there is a big difference between day and night-time temperatures. High car dependency is in large part determined by these climatic conditions. Summer temperatures in Riyadh reach 57°C, which results in a low proportion of trips made on foot or by bike. The elderly, children and those with special needs may not be able to walk at all during most of the summer, especially during the day. The large geographical area the city covers (as described in Section 2.3) contributes further to the increase in private car use, since many destinations are not within walking or cycling distance, even without taking the climate into consideration.

Correspondingly, the pedestrian environment is not well developed, with limited or no provision for sidewalks in most instances along major roads, and discontinuous sidewalks where these do exist. It's difficult for pedestrians to cross streets, given the wide intersection spacing, high speed and volume of traffic and the general lack of provision for pedestrians at signalised intersections (Alfozan, 2011).

Clearly, there are several complex and compelling reasons why car dependency in Riyadh is so high. While conferring many perceived benefits on Riyadh's citizens, however, this car dependency brings a number of disadvantages, one of which is severe congestion. Congestion, as a concept, is defined and explored in the following section.

2.5 Congestion

Talukdar (2013) defines congestion as: essentially a relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the system actually performs.

In transportation engineering terms, congestion can be described using three interrelated factors: speed, flow and density. Speed, of course, is the rate of vehicle movement. Flow is the rate at which vehicles pass a given point measured over a specified time period (e.g. vehicles per hour). Density is the number of vehicles occupying a unit of road space at any given moment (e.g. vehicles per mile).

Every transport facility has a characteristic relationship between these primary traffic parameters, a relationship that forms the core of transportation engineering and is known as the Greenshields Model. So-called macroscopic stream models, of which the Greenshields Model is the best known, represent how the behaviour of one parameter of traffic flow changes in respect to another. Figures 2.10, 2.11 and 2.12 illustrate the relationships between speed, flow and density according to the Greenshields Model (T. Mathew et al., 2007).

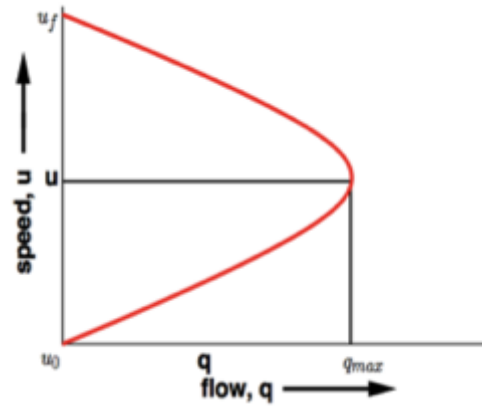


Figure 2.12 Relationship between speed and flow (Source: T. Mathew et al., 2007)

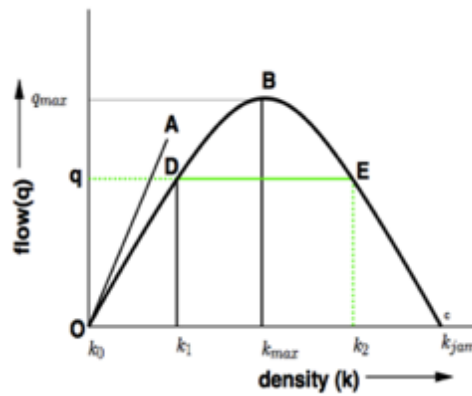


Figure 2.13 Relationship between flow and density (Source: T. Mathew et al., 2007)

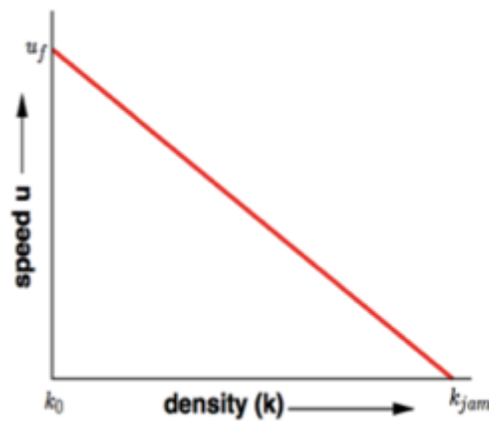


Figure 2.14 Relationship between speed and density (Source: T. Mathew et al., 2007)

According to Mathew et al. (2007), the most important of the fundamental relationships is the one between speed and density (Equation 1). The Greenshields Model proposes a

simple relationship between these two parameters, one that is assumed to be linear (T. Mathew et al., 2007). The equation for this relationship is shown below:

Equation 1 Greenshields Model equation

$$v = v_f - \left[\frac{v_f}{k_j} \right] . k$$

where v is the mean speed at density k , v_f is the free-flow speed and k_j is the jam density. The equation shows that when density approaches zero, speed approaches the free-flow or design speed of the road (i.e. $v \rightarrow v_f$ when $k \rightarrow 0$).

Congestion, as experienced by users of a transport facility, occurs when speeds are low and densities high (Talukdar, 2013). It's important to note, however, that, even in these conditions, traffic flows can be high. Indeed, there is an optimal point at which these three factors balance to give the maximum capacity available (see Figure 2.13). Beyond that point, the infrastructure's performance is suboptimal, causing congestion (Talukdar, 2013).

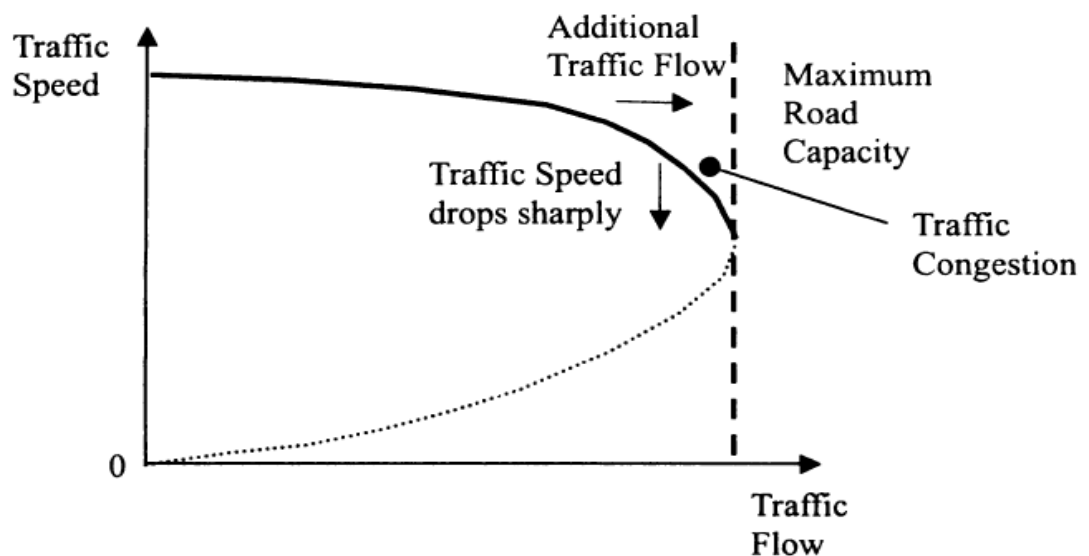


Figure 2.15 Speed-flow relationship and traffic congestion (Source: Talukdar, 2013)

An interesting feature of congestion is the difference in the way a transport user experiences it and the way a transport engineer defines it. An unpleasantly crowded, slow-moving road might be congested from the driver's point of view, but may in fact be performing at its maximum engineering and economic capacities. There are thus several different measures of congestion. A selection of these is defined in Table 2.2:

Table 2.2 A summary of different congestion measure indicators, meanings and definitions (Source: Victoria Transport Policy Institute, 2011; Author)

Congestion Indicators (Measures)	Meaning and definition	Whole Riyadh data (average)	Study area data	The sections of the thesis that discuss these indicators
Roadway Level of Service (LoS)	Congestion density on a particular roadway or at an intersection, rated from A (uncongested) to F (extremely congested).	F	F	5.5.1
Journey Time	The ratio of peak period to free-flow travel times, considering only recurring or normal congestion delays.	1380 second (MOT, 2015)	4144 second	5.5.2
Traffic flow*	Number of vehicle flow per road	n/a	1225 vehicles	5.5.3
Queue length*	The length of the queue that arises due to congestion	n/a	146 meter	5.5.4

* This indicator has been modified by the author

Based on all of these measures, it would be possible to argue that some of Riyadh's main thoroughfares are indeed congested. It is for this reason that public transport appears an attractive way of reducing vehicle numbers and traffic density and, in turn, increasing speeds. As mentioned earlier, public transport is one of the key factors behind congestion issues, thus, it is time now to study public transport in Saudi Arabia. The following section discusses public transport in detail.

2.6 Public transport in Saudi Arabia

Although Saudi Arabia, and Riyadh in particular, is heavily car dominated, there is still a public transport sector, albeit a small one. This section examines its development and the issues which have arisen. These provide clues as to what might await future public transport provision, and highlight why theories such as policy transfer are so important.

The Saudi Arabian Public Transport Company (SAPTCO) was established in 1979 as a public company with a government subsidy. It has been the regional and national public transit operator with a monopoly on transit services within and between Saudi cities. In Riyadh, despite this granted monopoly, private operators still provide deregulated transit services across the city and have done so since the 1960s, creating competition for SAPTCO (Al-Dubikhi, 2007). Alomran (2015) concludes that 'poor performance by SAPTCO' constitutes a greater obstacle to a more efficient transport system than the fierce competition from unregulated bus services, or jitneys as they are known locally (see Figure 2.14).

The situation at present in Arriyadh is quite different. Public transport is sparse with the main provider, SAPTCO, running a few buses that attract almost exclusively low income expatriate commuters and serving a very limited area of the city. Coasters (the privately owned mini-buses) provide a competitive service on 10 routes with, it is believed, around 1200 vehicles. It is estimated they carry around 83,000 passengers daily. Daily public transport passengers varied about 100,000 passengers and that the SAPTCO buses travelled 15-20% of this traffic with no available data of the current occupancy.

These vehicles operate on major roads and have a distinctive design: the chassis is white, with an orange line in the middle and a blue, green or maroon lower half (Alomran, 2015). Their relative success is due to their cheap price of just SAR two per journey and their destinations (city centre and Old city). They are particularly popular with Asian expatriate labour. They carry approximately 60 passengers per journey with no designated bus stops (Alomran, 2015).



Figure 2.16 Public transport services in Riyadh: jitneys (left), SAPTCO (right)

One very important feature of public transport in Saudi Arabia is that women constitute less than 9% of the total SAPTCO ridership. Service coverage, which is mainly long distance and intercity, and the lack of regard for female privacy, are two reasons for the low female ridership on SAPTCO buses. In particular, the design of bus interiors and seats are not appropriate for Muslim women or families, and it is culturally unacceptable to share a seat or to sit very close to male travellers. Jitneys, which mainly serve the market for labourers and itinerant workers, do not carry women. The only culturally acceptable independent means of travel for women and girls is provided by the city's taxi services (Al-Dubikhi, 2007).

Equally, the availability of private cars and drivers is one of the main reasons women avoid using public transport. All businesswomen and female students depend on their own private chauffeurs or taxi drivers. It is beyond the scope of this thesis to dwell for too long on the complex cultural issues relating to this situation; but suffice it to say that the 'public' nature of public transport renders it inherently unattractive for female users in this society.

Lessons learned worldwide show that the introduction of public transport is not in itself enough to attract users. Since there is a direct 'competition' between public transport and private car use, the car 'wins out', not just on convenience and cost, but also on comfort in a hot environment, and privacy in a society which values this highly.

Overcoming these barriers is not simply an engineering issue of convenience or comfort, nor an economic matter based purely on cost, but there are also some deeply ingrained cultural factors which exert a strong influence over who will travel where and when. The issue of mode choice is thus central to the development of Riyadh's future transport strategy, as exemplified by the Riyadh Metro. The following section presents the future plans for Riyadh.

2.7 Future plans for transportation

In Riyadh today, there is clear evidence that demand exceeds road space capacity. Extensive and sometimes prolonged traffic congestion exists every weekday on parts of the Makkah Expressway and King Fahad Freeway, including the majority of other arterial roads in central Riyadh. As mentioned earlier, (ADA) has undertaken various studies into the city's developmental needs through the ongoing MEDSTAR project. MEDSTAR addresses the Saudi capital's strategic planning needs and recognises that the success of the expected planning outcomes will depend on having a coherent strategy to support urban mobility. Equally, high quality public transport is an important element of the mobility strategy contributing to Riyadh's economic prosperity. It follows that there is a need to identify a public transport system appropriate to this sprawling, culturally unique city (Al-Dubikhi, 2007): this is the direction that Riyadh has chosen.

Ironically, the Ministry of Transport devotes almost all of its budget to maintaining the current road networks and building more freeways (Al-Dubikhi, 2007). However, this unsustainable trend is unlikely to continue, particularly after the Council of Ministers authorised the Ministry of Transport to carry out comprehensive public transport studies not only in Riyadh, but in all Saudi cities, regardless of size, in 2003. Interestingly, the ministry wrote back to the council seeking a specific budget for the consultation work for conducting transit studies for all places except Riyadh, since the city comes under the authority of the ADA (Al-Dubikhi, 2007). It is thus an exciting time for transportation research in Riyadh.

Emblematic of this shift in thinking is the Riyadh Metro, which has been detailed previously (see Section 1.1.3). Al-Dubikhi (2007) predicted that a new public transport system would be constructed, consisting of a metro system of six inter-connecting lines, integrated with a rapid bus transit network using dedicated highway lanes. The aim is to revolutionise the way in which the people of Riyadh, and the hundreds of thousands of visitors who come each year, travel around the capital. It is hoped that, by 2020, when the public transport system has become fully operational and citizens have become used to its immense advantages, the capital's roads will become markedly less congested. The expectation is that the minority who still feel the need to travel by car will experience faster journeys, without the frustrations of traffic jams. The research set out in this thesis will deal specifically with public transport as one of the future scenarios of Riyadh transport (see Chapters 4, 6 and 7).

2.8 Women allowed to drive next year.

On 26th September 2017, around a month before this research was submitted, a royal decree was issued giving women the legal right to drive in the Kingdom of Saudi Arabia from June 2018 for the first time. The decision falls within the framework of the Saudi Vision 2030, which aims to increase Saudi female empowerment through economic development and by raising the percentage of female workers in the Saudi economy. Saudi women have, until now, been getting around by hiring drivers or by travelling with male family members, or by using university and school buses.

The way they travelled depended on their economic situation and income. But studying the impact of women driving on Riyadh's transport network is quite hard at this time, since this decision has only recently been made. At the time of completing this research, there isn't enough available information or reliable statistics. The reasons for the difficulties can be divided into two main factors - economic and demographic. In terms of economic factors, the family's standard of living and employment has an impact.

Demographic factors are more complicated, since a Saudi community has many different ways of thinking, this includes; culture norms and the level of education, so, some women still struggle with their family guardianship, at least initially. The key point here is that many rural families prefer their girls and young women to use public transport to travel to school/college/university/work believing this to be the safer and cheaper option.

The new government initiatives and policies around women driving have prompted all government and private establishments to support this law as a step on the road to equality between men and women.

2.9 Conclusion

This chapter contributes to the overall research objective by developing an understanding of the range of factors which have contributed to Riyadh's current traffic situation. The specific research questions to be answered by this chapter were as follows:

Research question 1: What are the main aspects of transport that have contributed to Riyadh's current traffic situation, where almost 100% of residents are dependent on private car use?

Urban growth in economic activity and population in Riyadh has seen an increase in mobility. This, alongside several other important structural and cultural factors, has generated high levels of car ownership and car use. However, the research found that the main aspects of transport that contributed to Riyadh's current traffic situation, which is almost 100% dependent on private car use are:

- North American patterns of urban development

Saudi cities resemble American patterns of urban development and transportation more closely than those in Western Europe. Many cities, especially in North America, have decentralised homes and jobs, leading to growth in suburb-to-suburb commuting and a corresponding shift from public transportation to the car

- Cheap petrol

A major factor in Riyadh's car dominance is that petrol is cheap. At the time of writing a litre of petrol in Saudi Arabia costs USD 0.2 compared to USD 1.45 in the UK and even USD 0.62 in the US. Fuel prices, therefore, are not the barrier in Saudi Arabia that they might be in other locations. This is because Saudi Arabia is the one of the world's largest oil producing nations.

- The kingdom's economic and demographic features

Private cars are affordable to many people on a lower income, and this largely compensates for the lack of an effective public transport system. Moreover, people with access to cars simply never use public transport. The availability of private cars and their low usage costs contribute strongly to this. In terms of the economic aspects, Saudi Arabia has experienced continued economic growth which has attracted migration from within the country and from foreign countries.

- The effects of the climate on walking

The climate of the city of Riyadh is very hot in summer and cold in winter and characterized by low humidity throughout the year, especially in the summer, and a large difference between day and night temperatures. High car dependence is in large part determined by these climatic conditions.

Research question 2: What are the stages that contributed to Riyadh's current form in terms of its road network?

During the 1960s, the Saudi government began creating the first master plan for Riyadh. The Greek American consultant planner (Doxiadis) was appointed to design it. Doxiadis's plan was well adapted to private car use, as were many other similar master plans in the 1970s. Doxiadis designed the new city centre to the north of the Old city because of the need to build more service buildings (ministries, government departments, etc.). In Riyadh, according to Doxiades master plan, activity spines were proposed each to be serviced by mass freeways.

There was a corresponding need to build more residential neighborhoods and more activity centers, and thereby an overall increase in demand for travel had to be served more efficiently. The means by which this demand could be serviced was via private car (Al-Dubikhi 2007). An interesting feature of the Doxiadis period was that citizens of Riyadh were able to buy a house on land in the new city under the availability of money during the oil boom. This too had a substantial affect on trip types and mode choices which remains to this day.

Research question 3: What are the current public mobility services and issues?

In Riyadh, public transport provision is generally poor. It is mainly provided by the Saudi Arabian Public Transport Company (SAPTCO), established in 1979 as a public company (AlGadhi, 1994). Unregulated transport services compete with the state provider, but mainly in the provision of transport for itinerant workers and labourers. In both cases, though, public transport serves only a narrow market. Most notable is the almost complete absence of female service users, who are put off by the lack of privacy and other factors which run counter to Islamic and Saudi norms. Lessons learned worldwide show that the introduction of public transport is not sufficient in itself to attract ridership. This is even more apparent in Riyadh. Despite this, Riyadh's transportation plans are founded on a public transport concept, namely the Riyadh Metro project. The aim is to revolutionise the way in which the city's inhabitants, and

the hundreds of thousands of visitors who come here each year, travel around the capital (Al-Dubikhi, 2007)..

In summary, meeting these aims means addressing the factors and issues raised in this chapter, what emerges from Riyadh's developmental history and future is the need to go beyond conventional engineering solutions to consider the 'whole system' effects of engineering, people, society and culture (Al-Dubikhi, 2007). In the following chapter, the research focus narrows and deepens by mapping the theory of policy transfer to Riyadh's situation. In other words, just because a public transport solution has worked in other cities, that doesn't necessarily mean it will work in Riyadh. Policy transfer looks at this question in detail.

CHAPTER 3 Master Plans and Policy Transfer in Riyadh

3.1 Introduction

Having surveyed the history of Riyadh's modern development from oasis to metropolis in Chapter 2, and reflected on the main transport planning issues and concepts, research questions one, two and three have been addressed. The thesis now moves on to confront the next set of research questions. These are as follows:

Research Question 4: Of all the possible configurations and transport policies Riyadh could have chosen, why these policies specifically?

Research Question 5: In what way is the theoretical framework of policy transfer evident in Riyadh?

Research Question 6: Is there a risk that policy transfer issues could arise with new 'bought-in' projects such as the Riyadh Metro?

Policy transfer is defined as a best practice to resolve/address a specific issue within a city/country which is a worthy model for others to use when dealing with similar issues. (Peck, J., 2011). (See Section 3.3 for more definitions). This research operates from a strong multidisciplinary platform, linking transportation engineering, planning and urban studies together to explore the issue of policy transfer as it relates to Riyadh. For example, the Riyadh Metro is a paradigm case: it is a transport infrastructure that has proven successful in other (usually Western) nations, and its application in Riyadh is expected to have similar benefits, despite Riyadh's cultural and climatic uniqueness. Moreover, this thesis will make a number of new contributions to theory.

From Chapter 2, it is clear that Riyadh has experienced accelerated growth and has at various times, from the Doxiadis plan (the first master plan for the city) to MEDSTAR (the latest master plan, see Chapter 2), looked to experiences of other cities. This chapter contributes to the thesis by relating the formal concept of policy transfer to the

specific situation pertaining to Riyadh, and establishes whether it is a relevant and useful framework of analysis. For the reasons mentioned in Chapter 1 (problem statement) and Chapter 2 (city master plan and casual factors affected on Riyadh transport system), it would certainly appear to be appropriate and, if so, it provides a useful focus for the research. This includes mapping the existing policy transfer theory to the situation pertaining to Riyadh, and an extension of existing theory to take account of unique socio-cultural and climatic factors.

On a more practical level, it enables the research to confront a potentially critical risk for Riyadh: that new 'bought in' or 'off-the-shelf' projects, of which the Riyadh Metro is a leading example, may not be appropriate to the Saudi context, and may not perform as expected despite success in other cities. To analyse this issue using the policy transfer lens, this chapter will address, analyse and discuss the following topics:

- An overview of decision making within the Saudi context
- Policy transfer definition and issues
- Urban transport policies in the Arab world in general, with particular emphasis on policy transfer aspects
- Urban transport policies in Riyadh and, again, the policy transfer aspects therein, with some previous examples provided

3.2 Overview on Saudi transport decision making

Before addressing the issue of policy transfer, it is useful to set it within the wider context of decision making in Saudi Arabia. Here, the effects of the 1960's oil boom are significant. As explained in Chapters 1 and 2, expanding national wealth made hundreds of millions of dollars available to the government to allow for continued development (Mubarak, 2004). Indeed, Saudi Arabia is working hard to use this oil wealth to promote its citizens' welfare, and huge budgets continue to be spent on infrastructure projects (ADA, 2015; MOT, 2016).

A particular hallmark of decision making in Saudi Arabia is its hierarchical nature (this is discussed in Chapter 4). Generally, the Saudi Royal Court sets the country's strategic direction, with tactical and operational decisions flowing downwards (this is discussed in detail in Section 4.2). One benefit of a strict hierarchy is that significant national resources can be mobilised quickly, which in turn favours large-scale projects (al Dubaiki, 2007). This is in contrast with infrastructure development in other nations.

In the UK, for example, the decision to build a third runway at Heathrow Airport cannot (at least politically) be made hierarchically from the top down (Nulman, 2015). The advantage is that complex fine-grained solutions can be 'evolved' from the bottom up rather than imposed from the top down (Nulman, 2015). The disadvantage, of course, is that bottom-up processes of public consultation and 'localism' mean the project has been discussed since the 1970s, but is still not built (Nulman, 2015).

In Saudi Arabia, the expansion of much-needed services became part of the national plan (Mubarak, 2004). Part of the problem with the development of necessary public services was a lack of communication between government ministries. Public services for road construction, for example, were often uncoordinated with residential construction and so created heavy traffic and transportation problems (Murbarak, 2004). The lack of coordination in the development of the sprawling city was so bad that in 1985 the government halted all further construction until development could be brought under control to a certain extent (Murbarak, 2004). It was felt that the lack of specialist expertise or 'specialist elites' had been a hindrance to coordination.

Arising from this was an interesting situation. In Riyadh, the availability of capital was less of a problem compared with other cities, but the rate and scale of change brought about by large influxes of money gave rise to new problems, in this case a disconnected planning and development process. A secondary – but still important – side effect of this was that it created a perceived need for outside expertise.

The desire for coordination is in large part responsible for the appetite for master plans (such as the Doxiadis one of 1972). Embedded in these master plans were a number of

Western ideas about the form and structure of cities. As mentioned earlier, such huge projects, due to the lack of specialist elites, were bound to differ from indigenous ideas in terms of the demographic characteristics and that will be justified in this section (3.3).

In recent times, this has manifested itself as a need to maintain town centre viability and to reduce the impact of the car on the resource use and environmental pollution. It is only through a combination of strategies that progress can be made towards sustainable development objectives by using a combination of strategies. However, to reduce car use, it is necessary to promote cities as desirable places to live in, with a high quality of life. Good local accessibility and high-quality public transport are essential components of this.

Moreover, transport investment in urban rail infrastructure is seen as major tool in shaping urban structure and promoting economic development. Changes in accessibility resulting from a new rail infrastructure should encourage new development around stations – at least, that is what the experience of other cities suggests (Preston, 2010).

According to Baniester (2006), many cities, such as Los Angeles, Frankfurt, Portland etc., have invested in new rail systems, and some of the associated development has been privately funded. Offices, shops and commercial centres have formed an integral part of that development. As redundant land around railway stations has become available, new development has also taken place. This compact and high-density development is a direct result of changes in accessibility, and much of the recent new prestige office development in city centres has been of this structure (Baniester, 2006). Similarly, in many historic cities not designed for the car, and other medium-sized cities, smaller-scale bus and pedestrian-oriented changes have taken place (OECD, 2014).

As mentioned in Chapter 2, Riyadh has changed from being a small pedestrianised city before the advent of the automobile in the 1940s to a capital of eight million people today. In Saudi Arabia, there is an appetite for high levels of coordination to ensure best

use of the available funding (ADA, 2015; MOT, 2016). There is also a tendency to seek outside expertise to help achieve this (See Section 3.6.7).

As mentioned previously, there is a critical long-term risk of bringing these policies from another context and for them to prove less effective than expected. This is where the concept of policy transfer provides theoretical robustness and insight. The following section looks at the concept of policy transfer and the key issues debated in the wider literature review.

3.3 Policy transfer

Dolowitz and Marsh (2000: 5) defines policy transfer as *“a process in which knowledge about policies, administrative arrangements, institutions and ideas in one political setting (past or present) is used in the development of policies, administrative arrangements, institutions and ideas in another political setting”*. Another short definition by Hoyt (2006) says: ‘Policy transfer is a widespread practice’. In addition, this research has defined urban policy transfer as: transferring the successful urban plan/solutions that succeed to facilitate/resolve an urban issue somewhere to be implemented for the same issue within elsewhere (Dolowitz et al, 2000; Hoyt, 2006; Martínez, 2004). Although the literature clearly demonstrates the detailed processes and the main elements of policy transfer, it is descriptive rather than theoretical; and every policy lends itself to different aspects which may not apply to other policies in terms of policy transfer or implementation.

According to Martínez (2004), policy transfer is an ancient phenomenon, especially in the field of public administration. There are wider examples of administrative reforms and innovations that have been transferred from one national or regional context to another. Martínez (2004) concludes that three factors can produce policy failure in during the transfer process: a) **Uninformed transfer**: the borrowing country has insufficient information about the institution or policy transferred. b) **Incomplete transfer**: even if transfer has occurred, crucial elements of the policy in the original country haven’t been introduced. Lack of motivation or capacity may be behind this

failure. c) **Inappropriate transfer**: a common case in which the differences in economic, social, political and ideological contexts haven't been taken sufficiently into consideration (Martínez, 2004).

McCann (2011) proposes an agenda for research into the spatial, social and relational characteristics of globally-circulating urban policies, policy models and policy knowledge. His conclusion draws on geographical, political and economic literature analysing particular social processes in terms of wider socio-spatial contexts, in part by maintaining a focus on the dialectics of fixity and flow. As seen in Table 3.1, the theoretical framework for policy transfer is subject to many factors, such as why the transfer is carried out, who is involved, and where they are from. In Riyadh, the needs of governmental development (especially in the era of the rise of Aramco, see Chapter 2) under the availability of money were the big challenge in terms of the socio-spatial context, including Islamic and Arab privacy and culture, and will be justified in Sections 3.5 and 3.6.

One assumption is that the notion of 'mobilities' offers a useful rubric under which to operationalise this approach to the 'local globalness' of urban policy transfer (McCann, 2011). The concept of mobilities didn't exist in Riyadh before the oil boom of the 1960s, which means that 'local globalness' did not begin until after the first master plan - this is presented Section 3.6. McCann (2011) also indicates that there is much research still to be done into the character and implications of inter-urban policy transfer with special reference to developing and expanding cities such as Riyadh (McCann, 2011).

As mentioned above, governmental development needs, which were fully founded, formed the reason behind policy transfer in Riyadh. Officials (including the mayor of Riyadh the Municipality and the Ministry of Municipal and Rural Affairs (MOMRA)) are involved and fully responsible for urban policies/planning (see Chapter 2). These policies were taken from global best practice by the 'specialist-elite' due to the shortage of local knowledge.

Indeed, there are a number of questions concerning policy transfer in terms of the theoretical debate, these questions were summarised within a policy transfer framework developed by Dolowitz & Marsh (2000) and shown in Table 3.1 These questions are: Why transfer? Who is involved in transfer? What is transferred? From where? What is the degree of transfer, and what are the constraints on transfer? How do you demonstrate policy transfer, and how can transfer lead to policy failure? The model was developed to classify the different types of policy transfer, and the different results it can produce. Moreover, this model has been applied to Riyadh to answer the Dolowitz model's policy transfer theoretical questions, as shown in the following table:

Table 3.1 Policy transfer framework developed by Dolowitz & Marsh (2000) and its application to Riyadh (by author)

Why transfer Want to Have to			Who is involved in transfer?	What is transferred?	From where transferred?			Degree of transfer	Constraints on transfer	How to demonstrate policy transfer?	How transfer leads to policy failure
Voluntary	Mixtures	Coercive			Past	Within a nation	Cross- national				
Lesson drawing (perfect rationality)	Lesson drawing (bounded rationality)	Direct imposition Conditionality - Loans - Business - Activates - Obligations	Elected officials Bureaucrats Civil servants Pressure groups Political parties Policy entrepreneurs Experts Consultants Think tanks Transnational Corporations Supranational Institutions	Policies - Goals - Content - Instruments Programmes Institutions Ideologies Attitudes Cultural values Negative lessons	Internal Global	State governments City governments Local authorities	International organisations Regional state Local government	Copying Emulation Mixtures Inspiration	Policy complexity Past policies Structural institutional feasibility - Ideology - Cultural - proximity - Technology - Economic -Bureaucratic - Language	Media Reports Conferences Meetings Visits Statements	Uniformed transfer Incomplete transfer Inappropria te transfer
Riyadh application											
Governmental needs development and needs are fully founded			Officials (Riyadh – mayor, Municipality, MOMRA	Urban policies Plan programmes	Global	n/a	n/a	Mixtures	Policy complexity Past policies	n/a	Incomplete transfer

3.3.1 Policy transfer: Key issues

Fundamentally, policy transfer assumes that public policies change and that policies can be changed (Rommerts, 2012). Changes in public policy are driven by social and economic pressures, or by the requirements of technological change and innovation (Rommerts, 2012). According to New and Innovative Concepts for Helping Transport Sustainability (NICHES), further research is required in the topologies of these aspects (social, economic, and the requirements that result from technological change and innovation) to understand the policy and planning process of urban transport.

Open questions concern such topics as multi-level governance, urban transport planning and improved partnership structures. Research particularly highlights the need for improved decision support tools to help stakeholders in urban transport identify the most efficient measures for working towards an integrated land use and transport system (Owens, S, 1998). This would require complex tools and models, which should nevertheless be easily applicable. Table 3.2 identifies some of the key policy transfer research needs and how these map directly onto some of the key contributions this thesis will develop.

Table 3.2 Policy and planning key issues (NICHES, 2007) and their mapping to the work contained in this thesis

Policy & planning issues		Mapping to present research
Decision support tools	<p>a) Need for easy-to-use decision support tools to assess the costs, benefits and efficiency of a wide range of policy options to address urban transport problems.</p> <p>b) Understanding the social and environmental impact of different transport policy options (also unintentional impacts – positive or negative). A decision support tool also needs to consider the application of integrated strategies and the use of innovative solutions.</p>	Chapter 5 describes a microsimulation-based policy transfer test bed for assessing the benefits and efficiency of a wide range of policy options.

Sustainable Urban Transport Planning (SUTP)	Better understanding of suitable planning processes for different context conditions needed (e.g. via analyses of good practice), which lead to integrated transport strategies. Integration of transport innovation in comprehensive mobility strategies.	An understanding of planning processes in the Riyadh context has been provided in Chapter 2.
Multi-level governance	Need to research different approaches to governance, e.g. in the field of land use; comparison of decision making on local vs. centralised level.	An overview of decision making in the Saudi context is provided in Section 3.2 of this chapter, and the decision making hierarchy is explored directly in Chapter 4.
Urban transport planning in the regional context	Better understanding of the reciprocal effects of actions on the local level (e.g. core city) on the regional level (e.g. surrounding communities) and vice versa.	Chapter 5 describes a microsimulation-based policy transfer test bed for assessing the benefits and efficiency of a wide range of policy options.
Partnership structures	Understanding of public-to-public, private-to-private, and public-to-private partnerships needs to be improved.	n/a
Actions on air quality	How to set an effective and specific (political) framework in which the industry is required to reduce emissions, e.g. by defining emission targets with which the industry needs to comply.	n/a

This table has been adapted to the main research topics. As mentioned in Chapter 1, this research is based on a multidisciplinary platform that helps to understand how to comprehend policy transfer and implementation on the ground. It is therefore important to know the key issues surrounding policy transfer.

As Table 3.2 shows, decision support tools and urban transport planning in the regional context in this research are used in Chapter 5, which describes a microsimulation-based

policy transfer test bed for assessing the benefits and efficiency of a wide range of policy options. In addition, this thesis provides an understanding of planning processes within the Riyadh context, as provided in Chapter 2 as the means of Sustainable Urban Transport Planning (SUTP). Multi-level governance, clearly shown within the Saudi context, is provided in Section 3.2 of this chapter, and the decision-making hierarchy directly explored in Chapter 4.

3.3.2 Constructive revitalisation

One of the main drivers behind various policy interventions is social and demographic change. The policy implications of this change are daunting, as Table 3.3 shows. Despite the strong link between urban transport and many social issues, these are frequently neglected in research programmes (NICHES, 2007), according to NICHES (2007), there seems to be a particularly urgent need to research the impact of demographic change on urban transport in Europe and North America, but also other topics such as collecting better data on travel behaviour, the needs and wants of users, ideas for making city centres more attractive and the social long-term effects of mobility measures.

Table 3.3 Social issues (Source: NICHES, 2007)

Issues	Description
Demographic change	Efficient understanding of the effect of an ageing population on the required urban transport and mobility patterns.
Better data on travel behaviour	Lack of data on travel behaviour, particularly for specific target groups (e.g. elderly people, inhabitants). The available data must be easily accessible.
Better understanding of acceptance	More understanding of the mechanisms of acceptance of new services and concepts by stakeholders e.g. partnerships, stakeholder integration and acceptance.
‘Real needs’ for transport and	Better understanding of the ‘wants and needs’ of users as well as the perception of user requirements by the operators. Assessment of the mobility culture.

mobility	
Innovative solutions for better quality of life in city centres	Beyond mobility, but with influence over it: maintaining the vitality of the city centre, the socialising human, car-free living, collective vs. individualised lifestyles.
Social long-term effects of mobility measures	Better understanding of such effects as social ‘gentrification’ following infrastructure improvements leading to fresh mobility and social exclusion issues.

The main question, however, is what are the best off-the-shelf options? In Riyadh, for example, related policies were in line with the city’s accelerated development under the availability of money, but the extent to which these policies serve all stakeholders’ needs is debatable. For example, the master plan(s) discussed in Chapter 2 serve urban expansion and governmental needs very well, but the disadvantages of a car-dominated society affect the transport system.

In other words, this – indeed every - policy inevitably serves one particular interest over all others. Turning to the present policy picture in Riyadh, which focuses on public transport and encourages dense living around a central urban core, this too can be seen as a constructive form of revitalisation (Peck, J, 2011). This is reflected in Riyadh, where urban policies were the main contributor to the city’s formation and its modes of transport (see Chapter 2).

Hoyt (2006) argues that constructive revitalisation is a relatively new urban model which policy entrepreneurs have deliberately transferred, both within nations and internationally. Common features include urban development/renewal and the benefits have been found to cover city expansion or governmental needs. The disadvantages are (as mentioned above) failure to integrate with other elements of urban sustainability (see Figure 1.3). For example, in the early 1950s, the United States developed large shopping malls in suburban locations to accommodate car-focused customers. Affluent nations such as Canada and Australia, which also had plenty of space, quickly followed

suit. More recently, British officials implemented the Urban Development Grant after the United Kingdom's Department of the Environment examined 'potentially adoptable' policies for inner-city revitalisation, namely the US Urban Development Action Grant (Hoyt, 2006).

In Riyadh, the question arises as to whether constructive revitalisation will be integrated to enhance the elements of transport and sustainable- land use. From Chapters 1 and 2, it is evident that the previous rounds of policy transfer to Riyadh have had an enormous effect on its physical shape and transport modes. In summary, then, a policy such as constructive revitalisation, while very much 'in vogue' in western Europe, is not necessarily appropriate for Saudi Arabia, or at least would require some reinterpretation to suit the region's cultural and historical norms.

3.3.3 Specialist elites

Researchers have also addressed other issues of policy transfer. One of these concerns typologies which analyse social processes (Dolowitz & Marsh, 2000). A typology is a system for dividing things into different types, especially in science and the social sciences. In policy transfer, the typology is used to analyse the socio-spatial classification of common characteristics. Several researchers (e.g. Conradson & Latham, 2005; Ali & Holden, 2006; Conradson & McKay, 2007) have discussed how these typologies might hinder rather than facilitate analysis of social processes (McCann, 2011). For example, Riyadh's population has unexpectedly grown six times more than outlined in the Doxiadis plan within 13 years, in turn affecting urban growth, due to the shortage of typology in social studies (see Section 3.6 for more details).

Another key issue is how to identify who mobilises policy. This is because policy mobilisations are social processes (McCann, 2011). This tension is evident in the way in which the practice and process-oriented often parallel policy transfer research in producing typologies of key stakeholders. For example, Rose & Miller's (1992) influential statement on governmentality argues that, "[government relies on] designs put forward by philosophers, political economists, physiocrats and philanthropists,

government reports, committees of inquiry, white papers, proposals and counterproposals by organisations of business, labour, finance, charities and professionals” (Miller, 1992).

The key actors responsible for authoring these policy products have been referred to in the policy transfer literature as a ‘new specialist elite’ (e.g. Larner, 2002). “They range from international management consultants to small self-employed entrepreneurs, conference organisers, people in marketing, public relations and software development” (Larner, 2002). As already noted, it seems very clear that throughout Riyadh’s transport history, this ‘specialist elite’ has, and continues to be, relied on to solve a range of complex emerging issues, hence the continual need to buy-in so-called ‘best-fit solutions’. They are represented by a panoply of specialist consultants, expert infrastructure providers and foreign manufacturers.

Of course, there is a tension between the high levels of Saudi governmentality and the hierarchical nature of decision making, the reliance on an external ‘specialist elite’ and the strong drive towards ‘Saudisation’ and the use of home-grown human capital. Thus, this idea of policy transfer tensions between local decision makers (such as Riyadh’s mayor and, Municipality, MOMRA and ADA) and policy transfer elites (from outside the region) forms the key issue of this thesis.

3.3.4 Integrated transport policies and responsibilities

The responsibility for urban public transport usually has several layers, with central government being responsible for setting policies and creating legislation to implement and regulate those policies, and then with local government, to varying degrees (UNEP, 2011), having a delegated responsibility for the provision of services, sometimes directly and sometimes through further administrative structures (McCann, 2011). In addition, often there are various independent public bodies that consult, monitor or regulate upon such as disability access, passenger representation groups, and highway and passenger safety. Institutional arrangements for the direction, planning and operation of public transport have developed in various ways in different metropolitan

cities (UNEP, 2011). Institutional outcomes are influenced by the national culture, the national legal and regulatory structures in place and in particular the degree to which the transport policy decisions are taken by central government (Peck, 2011).

Likewise, the extent to which funding is approved and raised either centrally or at a more regional/city administration level is important (McCann, 2011). Furthermore, different direction and funding policies are sometimes applicable to capital cities from those in parts of the same country (McCann, 2011). For example, local transport in London is differently arranged from other metropolitan cities in England and both are somewhat differently arranged from those applicable in non-metropolitan areas. In addition, heavy rail transport is commonly quite separately administered and funded in a different manner than other local transport modes (Peck, 2011). Therefore, whilst examples will be drawn from experiences elsewhere, the solutions for Arriyadh will also take account of the local characteristics and traditions prevailing (Peck, 2011).

3.4 Urban transport policies in the Arab world

Arab transport policies are trying to solve numerous problems (Isam Kaysi, 2010). The urban population of Arab countries makes up 57.5% of the total population, compared with a world average of 49.1% (Isam Kaysi, 2010). Increased urbanisation and population growth have contributed to a rapid rise in the demand for urban transport and hence to a high rate of private car use and high traffic densities, particularly as mass public transit remains largely underdeveloped.

A transport sector brief by the World Bank (2010) concluded that “many of the Arab region’s large urban areas, where the bulk of Gross Domestic Product (GDP) is produced, face increasingly difficult transport problems with a high degree of traffic congestion, reduced mobility, and deteriorating air quality” (Kaysi, 2010). Transportation trends in Arab countries are characterised by:

- Rapid sprawling in the region’s major urban centres such as Amman, Baghdad, Beirut, Cairo and Damascus, with their populations of more than a million inhabitants
- Government-subsidised gasoline and diesel fuel in many Arab states

- An ageing vehicle fleet in most of the region's cities, where the average age of cars is 15 years, with countries of the Gulf Cooperation Council (GCC) being an exception. Cars are generally not well maintained, which contributes to high fuel consumption and elevated levels of emission rates (World Bank, 2010).
- Inefficient and inadequate public transport systems and excessive reliance on private cars
- Government policies that encourage private car ownership as opposed to other modes of transport such as public transport, cycling and walking
- Inefficient traffic management systems and insufficient public awareness of public transport
- Poor urban and physical planning, resulting in long travel distances between residential and service centre areas and places of work
- Inadequate governance to manage the transportation sector, seen in weak and insufficiently enforced environmental policies and regulations
- For most Arab countries, 'especially those with a large rural population such as Morocco, Egypt and Yemen, all-weather access in rural areas is limited by the poor condition of road networks and the inadequacy of basic transport services' (World Bank, 2010)

Additionally, there are high road traffic mortality rates relative to other regions of the world. Death rates due to road traffic accidents (per 100,000 of the population) in Arab countries are the highest compared with other regions of the world. In fact, between 1990 and 2000, there was a 20% increase in road accident deaths in the Middle East, whereas in Australia, Europe and Japan mortality decreased by 10% during the same period (Economic and Social Commission for Western Asia (ESCWA), 2009).

Although policies and measures envisioned by Arab countries are to some extent aimed at creating sustainable transportation systems (Arab Forum for Environment and development (AFED), 2009), deficiencies continue to exist in other major policy areas.

Population growth, industrialisation and economic growth projections have compelled Arab governments to invest in transportation infrastructure (AFED, 2009). According to

Kaysi (2010), about \$147 billion has been committed for infrastructure developments such as road, rail and public transport in the Middle East that would drive the growth of land, air and seaborne logistics industry in the region. Despite the size of this investment, the shortage of transport infrastructure remains an obstacle for Arab countries.

The paradox, when this is set against the global picture, is that unsustainable trends in the transport sector on a global scale are made obvious by the rapidly growing demand for transport activity (for both passenger and freight) where ‘it is predicted to roughly double between 2005 and 2050’ (UNEP, 2011). In the absence of an institutional capacity to introduce regulations and offer incentives for more sustainable patterns of transport, the economic, social and environmental costs of these trends will lead to deterioration in quality of life.

The effects of unsustainable trends in transportation can be summarised as follows, as adapted from United Nations Environment Programme (UNEP), (2011):

- Increased energy consumption, associated with energy security risks for
- Oil-importing countries, and opportunity costs for oil-producing nations
- High contribution to greenhouse gas emissions that cause climate change
- Traffic congestion and associated time delays and productivity losses
- Deterioration of rural and agricultural communities (through land misuse and migration)
- Inequitable access to jobs, services and markets, leading to increased poverty
- Weak contribution to equitable social development and cohesion
- Deterioration in public health (caused by air pollution and stress)
- Reduction in human safety (reflected in high death and injury rates from traffic accidents)
- Depletion of resources and increased contribution to solid waste loading

Furthermore, a low-performing transportation infrastructure (for the reasons motioned above) in the Arab region has adversely affected trade due to higher costs, delays and

uncertainty (UNEP, 2011). Since trade is one of the main drivers of economic activity, the transportation infrastructure is still not fully attuned to economic growth in many countries in the region (UNEP, 2011). An efficient transport network supports economic development, as well as being a solution to congestion problems (see Section 3.7).

The local and global transport situations interact to amplify both sets of problems in the Arab context. Population growth and urbanisation in Arab cities have led to rapid growth in urban transport demand, while improvements in the transport system and supply have not kept pace with this growth, creating a shortage in supply. This has caused high levels of traffic congestion and air pollution, and inefficiency in the movement of goods and people (UNEP, 2011), ultimately leading to a decline in Arab cities' economic productivity and competitiveness (UNEP, 2011).

Although action towards transport infrastructure growth and expansion is taking place in Arab countries, the benefits have not been large enough or sufficiently equally distributed, forfeiting social, environmental and economic opportunities (UNEP, 2011). To return to a point made at the beginning of this chapter, the need arises once again for more coordination and sensitivity around policy transfer.

3.5 Urban transport policies in Gulf countries

The Gulf Cooperation Council (GCC) holds regular sessions to study development proposals including transportation projects. These are subject to a vote among Gulf governments. Once such proposal is a \$25 billion railway line linking the six countries of the Gulf Cooperation Council (GCC), to be complemented by internal railway lines within each country. The Spokesperson of GCC has publicly announced the adoption of a railway between all countries, to be unveiled in 2018. Saudi Arabia is completing construction of its north-south railway project for freight use only, while the east-west railway line, intended to link Jeddah, Dammam and Jubail, will consist of both passenger and freight tracks (Kaysi, 2010).

Gulf governments – due to the availability of credit - support these transport improvements, and they are discussed and approved at annual council meetings attended by high-level decision makers. It seems clear that all of these projects should take account of policy transfer issues to avoid the possibility of 'bought- in' policies failing.

For example, just because a railway network functions well in western Europe does not make it an ideal solution elsewhere. Mirroring this shift away from road-based transport is a corresponding shift to alternative modes of transport and reducing the use of private vehicles, something that has been discussed in and between the GCC's member states. Promoting mass public transport means providing reliable, efficient and environmental friendly buses, trains and rapid transit affordably, particularly for lower-income groups.

The private sector can play a supportive voluntary role in promoting the use of mass public transport by offering employees group discounts or season ticket allowances (Kaysi, 2010). Similarly, one effective incentive that has proven successful in many countries to encourage commuters to shift from private to public transport is the provision of free shuttle bus services, which can be sponsored by government or private institutions (Kaysi, 2010). These policies have been transferred and implemented and are available today in the United Arab Emirates (UAE), where buses transport commuters from pre-determined locations to various locations, including malls and other service centres (Kaysi, 2010).

Furthermore, other incentives, such as introducing road and parking fees, are vital to reducing private car use. Moreover, motivating people to use carpooling or other ride-sharing schemes is one way of decreasing the number of vehicles on the road (AFED, 2009.) Achieving this might mean providing innovative incentives. Cash or parking vouchers for daily lift sharing, regular prize draws, dedicated parking spaces for car sharers and extra time off from work can all be used to encourage employees to adopt carpooling.

Most importantly, carpool lanes can be designed to encourage car sharing, thus

decreasing single-occupancy use of private vehicles (AFED, 2009). All of these are policy implementations which have been reasonably successful elsewhere (AFED, 2009). The next section starts to explore whether the same might hold true for Riyadh.

3.6 Policy transfer challenges in Riyadh

As mentioned above, the policy transfer is a comprehensive process that has a serious risk and unintended side effect. In the past, Saudi Arabia was sending the planners or decision-makers to the Western countries to learn and see what are the most successful urban solutions in these countries or may call the specialists/experts to the Kingdom to provide their solutions. This is, of course, the case with Doxiadis International where the poor communications make these solutions might be not easier to share with beneficiaries. Currently, Saudi Arabia continues to exhibit the best international experiences with a more considered view of society culture and their needs which is more easier to share with.

The same methodology is still being taken in Saudi Arabia when Royal council approves a new project. According to (ADA, 2015), in 2013, more than 80 engineering experts representing more than 20 engineering consultancy firms around the world (just three of them were Saudi firms) and the ideas of these experts were presented at one table (which basically means [off-the-shelf] solutions) where they were then presented and then agreed with three main consulting firms (see Table 3.1).

However, there are still many opportunities for governments (especially Arab) to benefit from experience and to share urban solutions about the best experiences around the world. The question remains how these solutions will be fitted in the societies they have brought to them.

This section analyses the current aspects of urban transport in Riyadh and the facts on the ground according to research sources, before investigating the challenges of urban transport policy transfer as experienced over the past six decades. The research will

explores how Riyadh reached this situation, and asks: where these policies came from and how they were implemented? When did the challenge of policy transfer appear? In summary, the next section traces the history and key features of policy transfer in Riyadh over time.

3.6.1 First challenge of policy transfer, (Doxiadis master plan, 1973)

As mentioned in Chapter 2, after Riyadh broke its ancient city walls and the oil age began in the 1940s, the Saudi government looked for consultants specialising in urban planning as its first step to urbanisation. It was felt there was no modern scientific expertise in this field in the country, or even the wider Middle East region. The decision to 'go modern', implying that 'modern' was a sensible and viable approach, reflects the policy transfer issue of both governmentality (who decided that a modern approach was desired) and specialist elites (who would devise a modern city master plan).

This departure from the city's traditional design standards culminated in the adoption of the first master plan in 1973 by the Council of Ministers (ADA, 2015). The plan was prepared by Doxiadis Associates International, a global consulting organisation based in Greece, which specialised in addressing the problems of human settlements all over the world (see Section 2.2.2). The plan provided for growth of the city to the north, parallel with the dry basin of Wadi Hanifah to the west. Wadi Hanifah is a system of deep, dry water basins located between flat plateaus and benches, and has traditionally comprised a chain of agricultural oases.

Doxiadis introduced a linear growth concept for the city along a central spine running in a north-south direction, thus avoiding the encroachment of the city on the Wadi Hanifah system. The common approach at the time was the gird network approach, which was adopted by the Doxiadis for new Riyadh. In addition, residential land uses have been allocated along the proposed activity-spine, which supports the idea of horizontal expansion as much as the city needs as well as using the zoning methods for the other land-use (e.g. commercial, historical, etc.). Furthermore, open areas and central parks were designed covering 11.5km² in an effort to revitalise the city centre and enhance

traditional social life.

The Doxiadis master plan introduced a physical plan that has been extended over time to accommodate a rapidly urban expansion. The main principles of the Doxiadis master plan, compared with the principles it replaced, are shown in Table 3.4:

Table 3.4 The 1973 Doxiadis city master plan principles compared with the existing old city, adapted from Doxiadis (Original; author)

1973 Doxiadis Master plan	Existing city before Doxiadis
A city-wide grid plan comprising a system of highways that circumscribe super-blocks of (2 X 2) km each blocks has its own services according to the zoning of land use, on the city's slightly rising and falling topography (e.g. Wadi hanifa). It sorted the city area into a functional land-use plan which has left it with a profoundly urban layout in terms of the forms of neighborhoods and street patterns.	A small walled settlement with a broadly radial pattern of roads and thoroughfares centered on ancient forts and palaces. the streets were lead to the king's palace and Dyira market (old market in Riyadh). Many pathways for horses and camels. Largely unplanned, organic functional land use (see Figure 2.5).
City-scale zoning regulations which included type and density of residential development, and minimum lot sizes for new residential areas and allows rapidly urban expansion. However, zoning regulations were stopped in relation to special area plans including historical and environmental area provision (such as king's palace, old mosque).	Weak zoning regulations and largely ad-hoc development. Restricted by limited space and existing structures without regard for urban considerations, the roles were only filled within the Islamic community.
The included design details of individual action area plans, covering 11.5km ² in an effort to revitalise the city centre and enhance traditional social life.	The main individual action area was the king's palace yard with some small, unplanned areas.

In completing these master plans, the authorities sought to control Riyadh and other major cities and manage rapid population growth (Mubarak, 2004). All of these notions – ‘manage’, ‘control’, ‘grid’ even ‘master plan’ are expressions of a particular mode of thought popular in the 1970s, but they are by no means the only way to enable coordinated city growth. Riyadh, like many other cities (particularly in the US) chose this approach because the benefits had been seen elsewhere (Mubarak, 2004). Detroit, for example, has a similar grid plan and emphasis on major arterial roads, and was often seen as a favourable case study to emulate (e.g. Hall, 1969).

In Riyadh’s past, simple physical planning did take place, mainly the laying out of land subdivisions according to local planning by-law measures. In contrast, city master plans were thought to overcome many of the problems of this localism by creating more economically and efficient urban systems in line with national economic growth plans (Mubarak, 2004), something that a smaller, more organically growing city could not to offer

The Doxiadis planners pictured a functional city set on a modular grid, a simple, straightforward, easily controlled and clear urban framework for the estimated city population which would be growing at 100,000 per year. The process of laying out land subdivisions using a grid started with the Manfouhah subdivision in the 1940s, but culminated in the arrangement of the whole city into superblocks of (2 X 2) km by Doxiadis (Mubarak, 1992). It was estimated that the 1970s plan would serve the city’s needs up to the year 2000. Other cities, such as Detroit, which inspired such highly functional master plans made some of the eventual outcomes of the plan seem inevitable: with improved access to more attractive (yet distant) neighbourhoods, people abandoned the traditional built environment altogether (see Sections 2.2 and 2.3).

From a policy transfer point of view, it can be seen how a ‘modern’ (in the 1960s/1970s sense of the word ‘modernism’ or ‘modernisation’) master planning approach, which seemed to enjoy success in places like Los Angeles or New York, led to effects in Riyadh that were not necessarily expected. Car use became excessive, and public transport could not compete (Mubarak et al., 2004). The weather conditions and Islamic

culture further disincentivised travel by active means or mass transit (Mubarak et al., 2004). Saudi Arabia's burgeoning oil wealth also meant that people, quite understandably, preferred the status and convenience of having their own vehicles.

Riyadh is considered a unique case in terms of its dramatic progression against policy transfer issues. Policy transfer - as mentioned above - has a huge impact on the city context which may not be covered within this PhD thesis. There should be focused, continuous research into each side effect. However, in the following section, the research investigates the main issues seen in Riyadh from the Doxiadis master plan, which is consistent with the research objectives of attempting to prove the risk of 'bought-in' policies from research sources.

3.6.2 Policy transfer issues with the Doxiadis master plan

As mentioned in the previous chapter, Riyadh's congestion problems stem in part from the application of Western plans and ideas, as generated and devised by Western consultants, as contracted by the Saudi government during the oil boom. In addition, the lack of specialist indigenous scientific expertise in the fields of transport or other areas was a major reason for contracting overseas expertise (especially Western expertise given the lack of knowledge even across the Arab region) for the kingdom. Furthermore, the huge amount of unused land owned by the government, and their financial reserves, contributed to the speed of the plan's implementation. In other words, the environment was suitable for the advancement of a city master plan (to the extent that it was viewed as a 'quick fix'). The long-term effects have been much less certain.

Since the contract with Doxiadis, there have been major challenges in Riyadh in terms of policy transfer and its implementation. The Doxiadis study serves as an excellent policy transfer case study, three aspects of which can be given particular attention.

3.6.2.1 Key issue 1: Population growth and urban expansion

Saudi society is Islamic, socially conservative and socially connected. This community supports marriage (and polygamy) and large families, which has led to rapid population growth (al Dubaiki, 2007). ADA has estimated the future population and the demands it will make on the city. Some of the key predictions are presented in Table 3.5 below:

Table 3.5 population/developed area (Source: ADA, 2017)

Factor	2016	2030
Population (million)*	8.1	12.3
Developed area	1806 km ²	2,500 km ²
Housing unit (Million)	0.960 units	1.74 units
Labour (Millions)	2.1	3.03

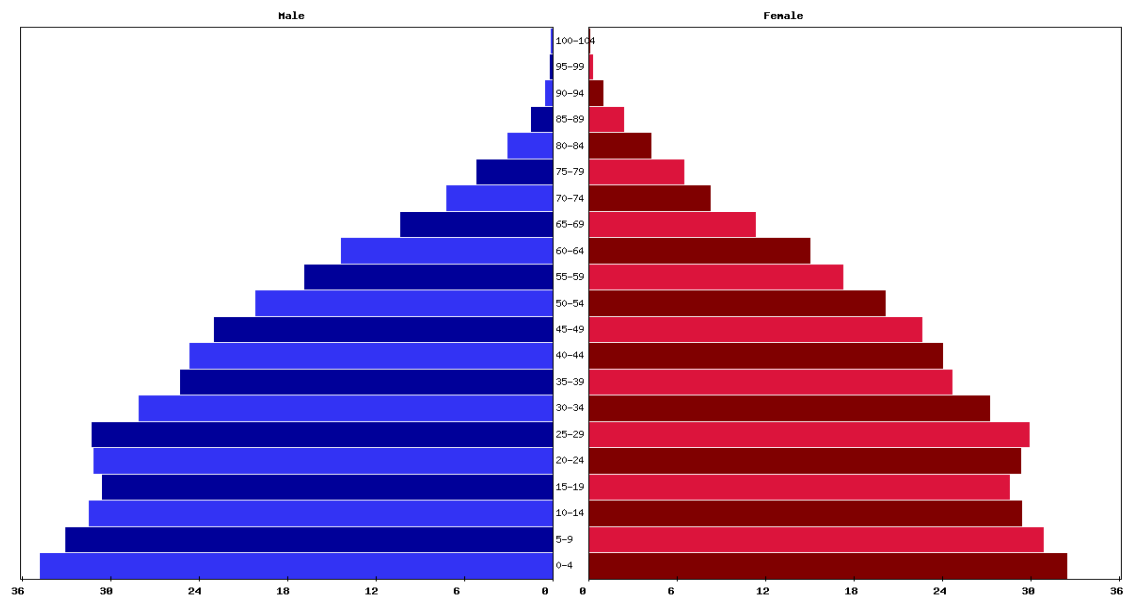
* Riyadh city includes sub-centers and rural villages within MEDSTAR.

MEDSTAR is the main structural plan regulating future development in Riyadh. It covers land that falls within the Riyadh Development Area (more than 5,000km²) that will meet the needs of 12.3 million people by (2030). The plan reflects the spatial and functional aspects of the relevant urban policies. It also specifies the distribution of main land uses, activities, business centres, transport systems, public facility networks, environmental requirements and open areas (ADA, 2015).

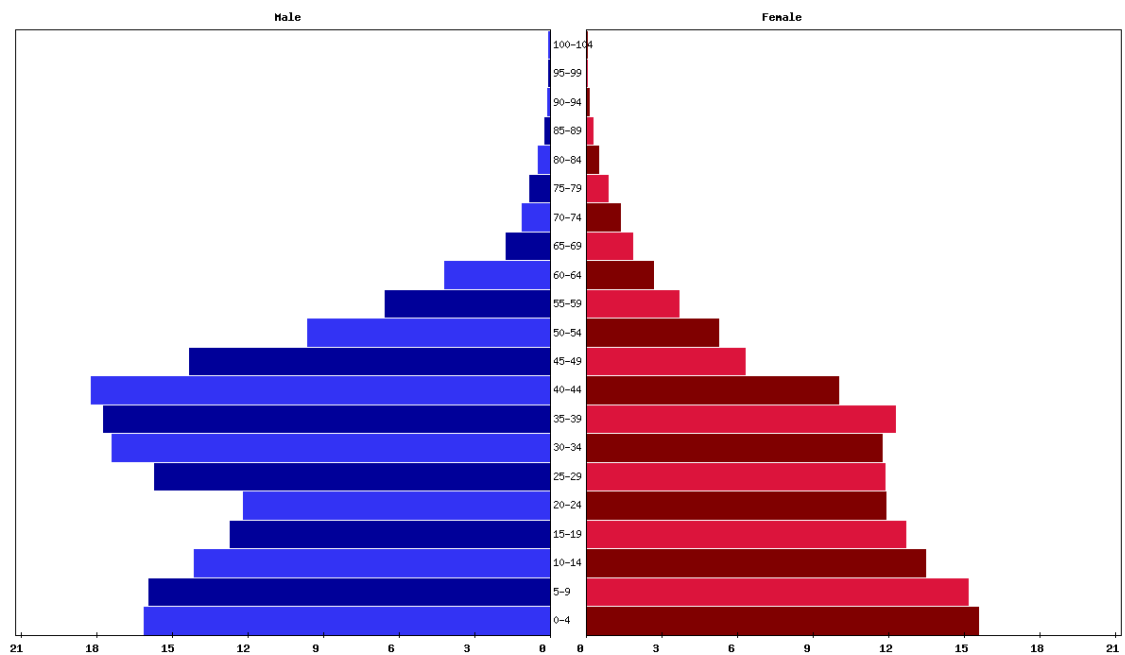
There are important population growth parameters which need to be taken into account in Saudi Arabia. In 1962, Doxiadis designed a ‘new’ Riyadh with a lack of demographic data, and that which did exist could not be applied to Saudi Arabia for many reasons (such as polygamy, which contributes to increasing family sizes and changes the population pyramid).

The following Figure 3.1 presents the world population pyramid on the upper figure and Saudi Arabia’s on the lower figure. Given that master plans are largely driven by

population growth and demographics, such a glaring difference must be taken into account if a policy, such as an ambitious city master plan, is to transfer effectively.



Population (ten million)



Population (hundred thousand)

Figure 3.1 World population pyramid on upper figure compared with Saudi Arabia's on lower figure (Source: World Life Expectancy, 2016)

The population pyramid shows two key things: a) the proportion of males is much higher than the proportion of females in the Saudi population, and b) there are high numbers of men in the age groups between 20 and 54 which is (working age). The reason behind that is the presence of guest or migrant workers to the country, these workers are predominantly male and not accompanied by their wives or families.

In summary, the characteristics of the age structure can be judged by three facts:

- 1) The proportion of young people is medium.
- 2) The average age is described as high.
- 3) The percentage of elderly is low.

Riyadh has also witnessed a dramatic spatial expansion over the period 1966-2014 (Table 3.6). Again, this is a key factor in future policy transfer issues, and is likely to arise at least in part because previous policy transfer issues were not fully taken into account. From 1966 to 1971, Riyadh expanded slowly, with only 525ha increase and a 0.2% annual growth rate. This slow urban expansion coincided with a period of recession (Abdu et al., 2002).

Subsequently, between 1971 and 1982, Riyadh experienced a remarkably swift increase in both population and urban mass. This growth was significantly affected by the oil boom (of the 1960s), the rapid increase of transportation infrastructure (brought about by master plans such as Doxiadis's), alongside cars ownership and other factors outlined in Chapter 2. According to Abdu (2002), two distinct patterns of expansion emerged: outward expansion and sprawl development. A tremendous outward urban expansion occurred between 1982 and 1994. After 1994, coinciding with slower economic growth, population growth and spatial expansion were limited. From 1994 to 2008, Riyadh saw development in urban areas mass, but the rapid spatial expansion of the 80s slowed down (Abdu et al., 2002).

Table 3.6 Shows urban spatial expansion (USEI) and spatio-temporal expansion between 1966 and 2014 (Source: Yusuf A. Aina et al., 2008)

Year	Urban area (km²)	Spatial expansion	USEI
1966	193	-	-
1971	198	525	0.20%
1982	334	13.56	4.50%
1994	437	10.339	2.30%
2002	498	10.061	1.20%
2008	571	7.38	1.30%
2014	647	8.9	1.7%

The population of Riyadh has increased by about 63% between 1996 and 2008. The percentage change per year for the period 1996 to 2008 in Riyadh is approximately 5.2%. The number of households in Riyadh has increased by 159.9% between 1996 and 2008, while the size of those households has shrunk (to 2.6 people per household). This has been a significant driver of Riyadh's current traffic congestion, and this increase was unexpected. The first master plan of Riyadh was designed by Doxiadis, and serves as a direct example of policy transfer problems.

Family growth was not taken properly into account in this plan. The population density of planned neighbourhoods was assumed to follow a Western pattern, but the reality of the Saudi family is very different. In other words, policy transfer issues were not sensitive to local culture/traditions.

3.6.2.2 Key issue 2: Road network patterns

As shown in figure 2.7, Riyadh's road topology has become a critical issue within the city. The Doxiadis master plan adopted the car as the main means of transportation. Thus, streets were designed in a hierarchical pattern that included freeways linking the city with the kingdom's other regions; expressways carrying high-speed traffic inside

the city; arterial streets carrying heavy traffic inside the city; collector streets joining neighbourhoods; and local streets traversing neighbourhoods (Al-Hathloul, 2002).

So-called 'activity spines' were proposed along the major highways, linking the sub-centres with the Central Business District (CBD), to ensure the vitality of those sub-centres (whose designs were based on Western city ideas). According to the traffic patterns and distribution in Riyadh, there was a high rate of internal journeys existing within several sub-municipalities (ADA, 2015).

All of these neighbourhoods are served by the main roads, and, in turn, this has made the road network more complex than originally planned. This makes the road network more complicated to navigate, and encourages further car use, while making the urban area less attractive to live in and travel across without a car. It also raises the question of why there was a need to locate sub-centres along freeways. In response to this critical question, in Phase 2 of the MEDSTAR project and during the process of selecting a preferred option, the study states that the consolidated pattern of development would be public transport-focused (ADA, 2015).

The road network pattern Doxiadis designed contributed to car ownership and attracted the population to the 'activity spines' under the factors explained earlier in Chapter 2, making the aims of the subsequent MEDSTAR project very difficult to achieve. In a way, Riyadh is 'locked in' to the pattern of development and use that the Doxiadis plan established. Attempts have been made to reverse this. In 1986, a bus, light rail or monorail system linking the sub-centres with the central metropolitan area of Riyadh was proposed, and is now being constructed. Activity spines were once again selected, among other things, to encourage the use of this transit system along the spines.

However, this vital suggestion was excluded from the final city structure plan (ADA, 1999) at the end of 1999. Instead, various freeways were proposed for current and future urban development, while the implementation of both a transit system and sub-centres is still lagging behind (Al-Dubikhi, 2007). In other words, the street patterns of the first master plan for Riyadh were transferred from American schemes and continue

to play a major role in the future of Riyadh's transport system, and that has been problematic for planning/transport.

3.6.2.3 Key issue 3: Integration of land use and urban transport

Riyadh faced another policy transfer issue as a result of the Doxiadis master plan. Within the plan, Doxiadis anticipated the transit model split would reach 45% by 1980, but this had actually fallen to 25% by 1991, based on the experiences of similar cities (Doxiadis Associates International, 1977:22; Al-Mosaind & AlGadhi, 2002). This original Doxiadis study was one of the motivations behind the foundation of SAPTCO in 1979 which, as discussed above, has suffered from competition from privately operated minibuses (Al-Dubikhi, 2007).

Large cities that rely solely on cars and commuter transit are at a serious competitive disadvantage in comparison with cities with efficient regular transit services, even if the car plays a dominant role (Al-Dubikhi, 2007). This is because of the lack of integration between land use and urban transport. In other words, if the activity spines were served by an efficient transport system, Riyadh wouldn't be facing this issue as it is now.

For the reasons presented above, although Riyadh has a first-rate road network and westernised street patterns, the transport problems and traffic congestion are often more serious than in other developed cities due to the lack of public transport and integration between land use and transport. Integration of land use and public transport can make a positive contribution to overcoming this problem by providing an alternative to the private car. This need is keenly felt in Riyadh and the Metropolitan Development Strategy has therefore suggested that adequate public transport for Riyadh (MEDSTAR, 2012) be provided as a remedial measure beside high capacity road provision (ADA, 2015).

A lack of integration between the transport system and how surrounding land is used has been a major impediment to building sustainable transport systems. This is because of the lack of connection between the transport integration ladder elements shown in Figure 3.4.

This integration has been defined as ‘a multi-faceted concept that includes a number of stages’ (Preston, 2010). Others have embraced its complexity by describing integrated transport as a scalar (Potter & Skinner, 2000), or by referring to the steps of an integration ladder (Preston, 2010; Figure 3.4).

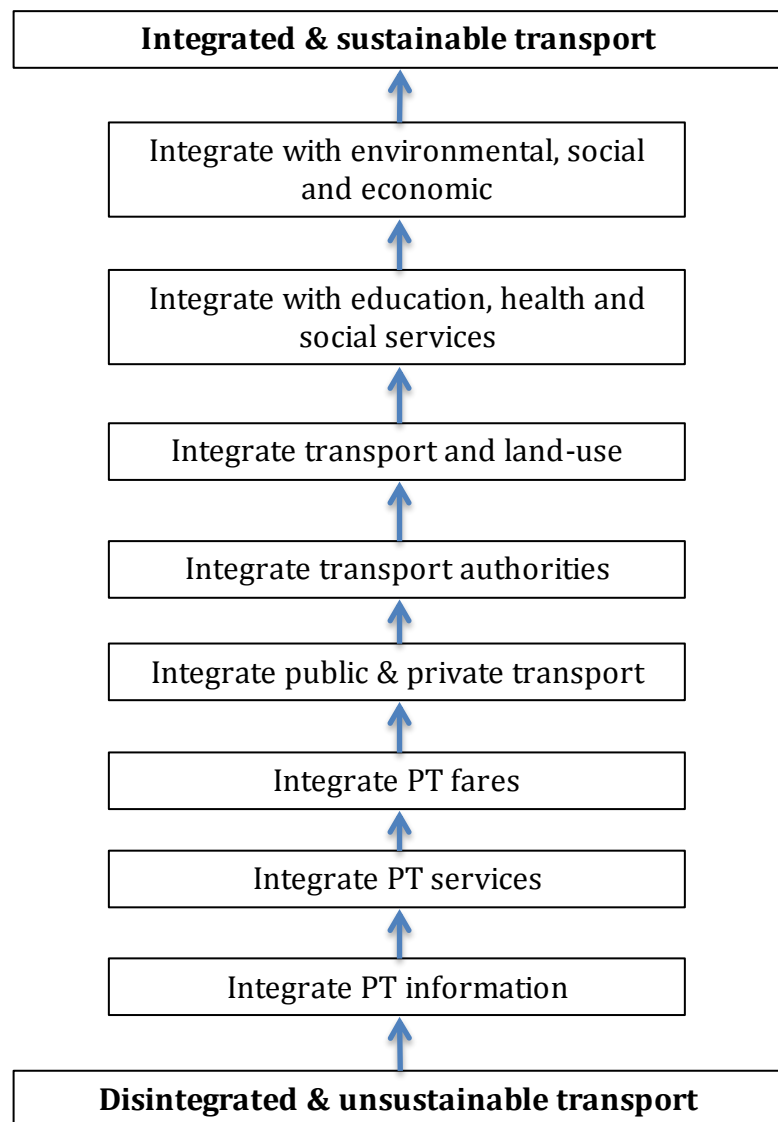


Figure 3.2 Shows the integration ladder (Preston, 2010)

Of all the policy transfer impacts, integrated transport is perhaps the most challenging. There are a number of reasons for the failure of integrated transport over the last decade (Preston, 2010). The first is the failure to define the concept. The second is the failure to operationalize the concept. The third is the lack of an evidence base on the success of integrated transport policies (Preston, 2010).

Evidence is now emerging in Britain on the benefits (and indeed the costs) of some aspects of integrated transport policies. The fourth, and perhaps the most crucial failure, is the lack of will in terms of politicians, civil servants and the general public to adopt the behavioral changes necessary for an integrated transport policy to succeed. A series of organisational and funding changes are proposed that could advance the prospects for integration (Preston, 2010). In Riyadh, however, an absence of coordination in the context of policy transfer within its first and second plans contributed to the absence of successful policies being implemented that would have helped make integrated transport more viable.

Many of the city's planners felt that the best way to create a cohesive and unifying identity for the city was to place limits on its physical area. All of the main master plans set boundaries on the city's growth, albeit ever larger ones. Part of Riyadh's second phase of development is the focus on limiting the barriers associated with its massive roadway system.

In summary, what is happening in Riyadh is a clear example that policy transfer from another context, even if successful, does not mean success elsewhere. Integrated transport and land use, for example, existed in America - where Doxiadis came from - but was not used in Riyadh. As a result of the consequences of the first plan – both good and bad - Riyadh had to update its master plan. The next section investigates the second of Riyadh's policy transfer challenges.

3.6.3 Updating the Doxiadis master plan (by SCET International, 1982)

As mentioned above, the lessons learned from policy transfer in the Doxiadis plan of 1972 (as explained in Sections 3.6.2, 3.6.3, 3.6.4 and 3.6.5) called on the Saudi government to update it, as described in Chapter 2. In 1976, SECT International – an urban design consultancy firm based in France - was retained by the Ministry of Municipal and Rural Affairs (MOMRA) to update the Doxiadis master plan. Following the oil boom of the early 1970s, so-called ‘mega land owners’ realised that money could be made laying out roads on the periphery of the city.

The original Doxiadis plan designated a city area of 204km² and did not foresee the exponential growth of the city’s population or the associated channelling of a massive financial boom that affected the whole picture in Saudi Arabia. By 1977, the city’s urban sprawl exceeded the original Doxiadis plan boundary of 300km² and covered a total area of 700km², resulting in an extraordinary urban sprawl. This resulted partly from the increasing privatisation of Saudi Arabian life and the increasing tendency to live in detached homes, but mostly from the real estate mania of the booming 1970s. SCET’s revised master plan (Figure 2.6), which was completed in 1982, included 250km² of vacant approved subdivisions. Subsequently, even more subdivisions were approved beyond the SCET boundary.

Riyadh’s suburban sprawl has been a result of factors not too dissimilar to those of other countries such as the United States, namely that investors, consumers and businesses have sought inexpensive land with low congestion. This naturally placed a high reliance on car travel, which allowed people to live some distance from their place of work due to the factors encouraging people to use private cars (see Chapter 2). This development resulted in a distinctive sprawl similar to the sprawl character observable in the United States (Mubarak, 2004).

In its development phase, the city sprawled into income-based inequities where services were unable to reach a large portion of the city’s residents (Mubarak, 2004). The growth of the city beyond its original walled medina left an infinite amount of space for growth

that in turn created several barriers for developing proper services for its residents (Gamboa, 2008). The lack of coordination with services in the development of the sprawling city was so bad that, in 1985, the government halted all further construction until development could be brought under control, at least to a certain extent (Murbarak, 1992). This two-year hiatus resulted in a reorganisation of construction and also included the planning and definition of the city's boundaries. As Riyadh expanded outwards, city agencies provided poor planning in the leasing and planning of land.

The city outskirts of the 1970s were about the half the radial distance from the city centre compared with today's boundaries. Agriculture and large land plots also proved somewhat troublesome to expansion. The Ministry of Agriculture contributed to the city's sprawl by setting aside inadequate land for agricultural use. Had the plots of land been large enough, there would be no encroachment by surrounding development on urban protection zones. When the land sizes are too small, it is difficult to maintain an agricultural character, especially when surrounded by expanding urban development. Current master plans are trying to address land use issues such as these by increasing pedestrian space in regions like the Olayya-Batha corridor. This will create pedestrian zones that are both functional and aesthetically pleasing, while also giving residents a cohesive feel and sense of community that were often solely associated with local mosques (ADA, 2015).

3.6.4 Riyadh current master plan

Currently, the ADA updates its overall city master plan every five years. Included within this plan is a comprehensive update and identification of the full urban needs of each part of the city. Riyadh's rapid expansion requires a comprehensive strategic plan to cope with this growth and meet the city's needs under the umbrella of studies, plans, ideas and perceptions related to development. Accordingly, ADA has started to prepare a comprehensive strategic plan for the city to lead, guide and organise future development, and provide a vision for the future while addressing the various development issues it faces now and in the future (ADA, 2015).

In 2010, according to the World Bank, “there are specific areas, namely road safety, women’s empowerment, and the accessibility of persons with reduced mobility (PMR), where the sector’s contribution could be enhanced if there was greater understanding of issues among governments and focused interventions whenever justified” (Kaysi, 2010). Although several Arab countries are signatories to the Convention on the Rights of Persons with Disabilities, none seems to have started to implement it in the transport sector, especially Saudi Arabia. Although action towards transport infrastructure growth and expansion is taking place across the country, the benefits have not been extensive or equally distributed, forfeiting social, environmental and economic opportunities.

One step the city is taking is the use of interest-free loans from the Saudi Arabian government – loans are fully covered by Ministry of Housing to support housing for those who need it. These loans have enabled countless businesses to expand and develop as far as needed to make Riyadh an important capital city (Gamboa, 2008). In order to start establishing Riyadh as a functioning capital city, the government set forth the different development phases needed for the city to grow.

Today, the MEDSTAR plan (see Figure 3.3) is continually being updated. According to the ADA, this is the strategic plan determining future development. The strategy develops future urban needs and drafts a strategic framework for the short and long term (ADA, 2015). “MEDSTAR reviewed the current situation of the city and defined the expected results of the metropolitan development process as well as the critical problems that may face it in all development fields through detailed studies on urban development sectors, in addition to suggesting alternative strategies to achieve these objectives in cost-effective ways” (ADA, 2015).

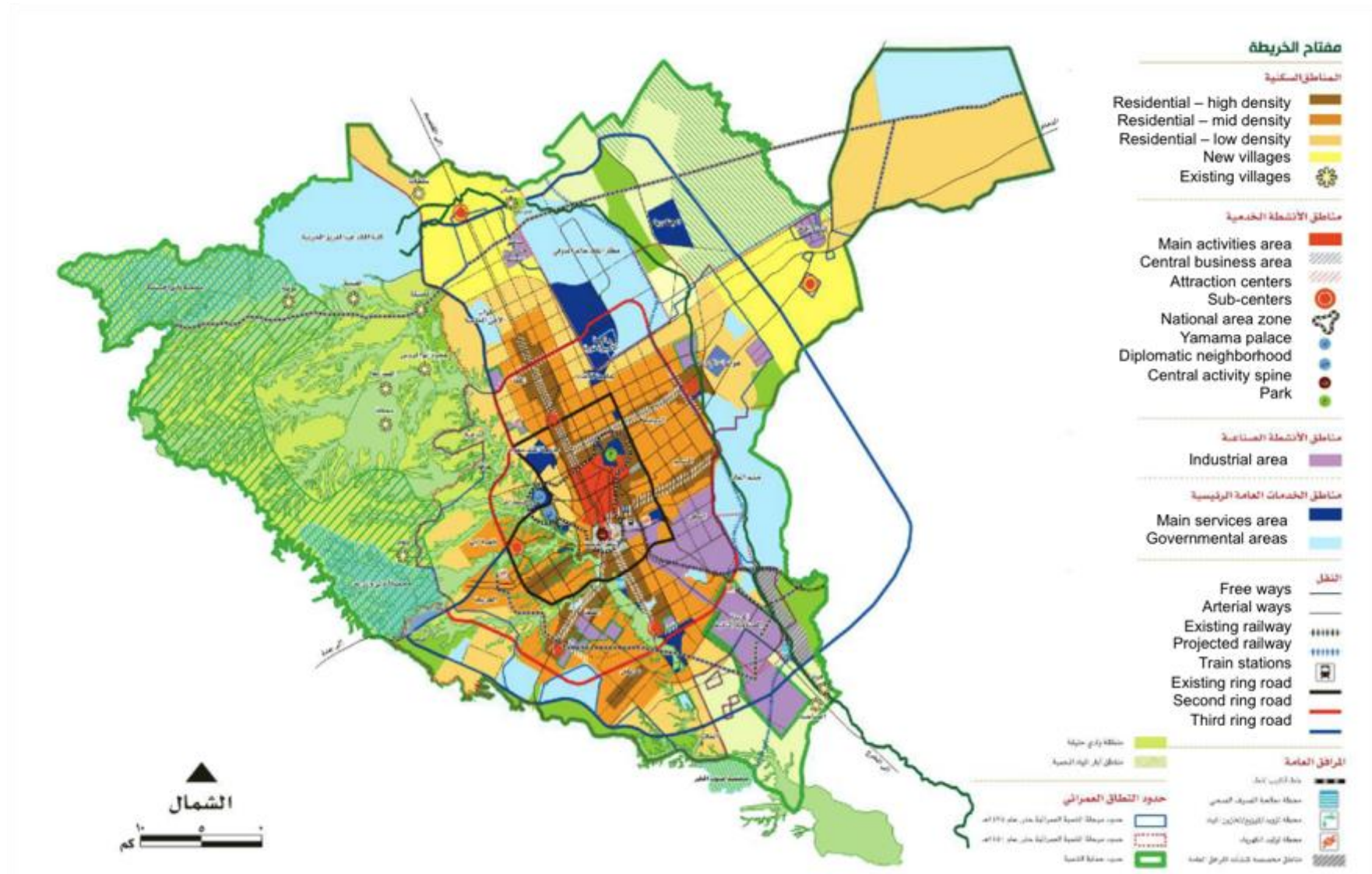


Figure 3.3 Riyadh's current structural plan (MEDSTAR) (Source: ADA, 2015)

Because so much of the city was built so recently, the ADA has coordinated and planned its expansion to ensure a modern highway system including two ring roads, the second of which is an eight-lane highway, as shown in Figure 3.5. A third ring road is still being built. As discussed earlier, these ring roads also represent one of the key issues of policy transfer, because most of these schemes were brought in from the Western capitals such as London and Los Angeles, among others. Projects to develop the transport system are ongoing and fully sponsored by the government to enhance the mobility services.



Figure 3.4 North-west leg, Riyadh, third ring road (Source: MOT, 2016)

3.7 Conclusion

This chapter contributes to the thesis by developing an understanding of why policy transfer is a relevant and useful framework of analysis. It has been argued that it helps to understand the complexity of Riyadh's transportation system by presenting the most important literature dealing with policy transfer issues and the application of policy transfer to Riyadh. Furthermore, that 'bought in' or 'off-the-shelf' projects such as the Riyadh Metro could represent a 'quick fix' (to the extent that it is a big project that could be implemented in one go) but which, in the long term, may not be appropriate to the Saudi context.

In addition, it has been found that solutions may generate unintended consequences or not have the desired effect i.e. that transport congestion may not be reduced to the level expected/planned. That may be an overly harsh assessment, but this chapter has shown how existing city master plans – and the Riyadh Metro is part of the current master plan have led to a range of unexpected side effects. Moreover, Dolowitz & Marsh's (2000) policy transfer framework model has been applied Riyadh to link the theoretical framework to understand policy transfer factors as comprehensive process. The specific research questions to be answered by this chapter were as follows:

Research question 4: Of all the possible configurations and policies Riyadh could have chosen, why chose these policies specifically?

The research found that the kingdom's approach to planning mirrored the planning followed by developing countries at that time. During the 1960s under the availability of capital with the lack of experts, Saudi Arabia's government has been attracting many western consultants to develop and solve urban problems. Perhaps the most important of these plans was the master plan designed by Doxiadis. This master plan played the main role of Riyadh's current urban form which is adopted private car as the main mean of transport. According to Peck (2011) Policy transfer is defined as a best practice to resolve/address specific issue within a city/country which is worthy model for others to be taken for similar issues.

The approach of contracting Western consultants to design the master plans was popular in many developing countries due to the shortage of experts (as mentioned previously) in the urban planning field. In policy transfer terms, this reflects the notion of a 'specialist elite'. Master plans themselves constitute comprehensive land use and infrastructure development plans, projected in tune with vigorous national economic growth schemes, all of which seek to facilitate economic prosperity and social stability by manipulating the spatial system.

The master planning approach operated on a large scale and was favoured over localised

‘organic’ solutions as a way of bringing about efficient, almost ‘machine-like’ cities. They were also the archetypal solution (in other locations) to rapidly expanding cities. They were long-range, multi-phase conceptualisations of a town’s growth. To that extent, master plans are an example of ‘governmentality’ which fitted well with the hierarchical nature of Saudi Arabian governance.

Research question 5: In what way is the theoretical framework of policy transfer manifest in Riyadh?

Riyadh has experienced rapid population and spatial growth, land use change and infrastructure development over the last 40 years. Various driving forces have caused spatial changes over time, mainly economic progress, population growth, government attitudes, the city’s master plans and the growth of transportation infrastructure. Riyadh exhibits two different features of urban growth, which can be identified as sprawl expansion and outward growth. It was found that the growth of transportation infrastructure has been mainly influenced by population growth (Mubarak, 1992). Not only is policy transfer manifest in the solutions to Riyadh’s transport challenges (e.g. a ‘specialist elite’ and ‘governmentality’), These challenges were at all aspects, which were often not in line with the Saudi culture or socio-privacy.

The demographic and Islamic situation of Riyadh reflects these challenges as a critical risk of how transferred urban policies. Governmental needs to development which is fully founded was the reason behind policy transfer in Riyadh, the Officials (Riyadh mayor, Municipality and Ministry of Municipal and Rural Affairs (MOMRA) are involved and fully responsible of Urban policies/Plans process.

These policies were taken from the global best-practice by 'specialist-elite' due to the shortage in the local knowledge. Indeed, there are a number of questions concerning policy transfer on the theoretical debate these questions were summarized within a policy transfer framework developed by (Dolowitz and Marsh, 2000) these questions are: Why transfer? Who is involved in transfer? What is transferred? From where

transferred, Degree of transfer, Constraints on transfer, How to demonstrate policy transfer, and how transfer lead to policy failure.

The model has been developed in order to classify the different types of policy transfer and the different results it can produce. For example, the accurate data of where does this policy come from and how to transfer it helps to consider the characteristics this society in order to avoid failure. Moreover, this model has been applied for Riyadh in order to answer the policy transfer theoretical questions in Dolowitz model which has been mentioned earlier.

Research question 6: Is there a critical risk that specific policy transfer issues could arise with new 'bought-in' projects such as the Riyadh Metro?

By mapping of the existing policy transfer theory to the situation pertaining in Riyadh and an extension of existing theory to take account of unique socio-cultural and climatic factors, the research has analyzed a potentially critical risk for Riyadh: that new 'bought in' or 'off-the-shelf' projects, of which the Riyadh Metro is a leading example, may not be appropriate to the Saudi context and may not perform as expected despite 'success' in other cities.

Yes. There is a serious criticism levelled at policy transfer/'bought-in' plans which include a wide range of social, demographic and economic aspects as well as social aspects such as culture and privacy. This chapter has considered three aspects of the failure of the Doxiadis master plan. These aspects are: a) population growth which has jumped six-fold above the Doxiadis growth forecast; b) street patterns that affect city form and c) integrated public transport.

Furthermore, this chapter has defined policy transfer and represented its implementation across the Arab world and in Riyadh specifically. Thus, the planner must consider policy transfer issues and their implementation to avoid the potential failure of any

‘bought-in’ projects (such as a new master plan, road networks or railways). The following chapter conducts semi-structured interviews with decision makers in Riyadh’s transport sector to help to generate Riyadh transportation future scenarios. Moreover, it also reveals more about policy transfer issues from a decision maker’s perspective.

CHAPTER 4 Riyadh Transport Stakeholder Interviews

4.1 Introduction

This chapter's main aim is to help generate future scenarios from the perspective of Riyadh's transport decision makers, and test these scenarios in the microsimulation Model (which will be built and calibrated in the next chapter).

In Chapter 2, we saw how Riyadh has grown from 'an oasis to a metropolis during a very short period, and how certain distinct transport planning approaches were used at different times to shape the city and its transport process as they exist today. In Chapter 3, we explored the role of policy transfer and how the origin of those transport planning approaches can affect their performance and implementation, especially where westernised approaches are applied to a quite different cultural context. In this chapter, we bring these two strands together to answer the following research questions:

Research Question 7: Where do Riyadh's traffic problems come from?

Research Question 8: How are policy transfer issues manifest in current decision-making?

Research Question 9: What expectations do key stakeholders have for current and future transport projects?

The researcher is fortunate enough to have been granted privileged access to key stakeholders in Riyadh's transportation sector, from government-level decision makers to practising transportation professionals. This access – which is not routinely granted – has been used to directly understand: a) what the policy picture is in Riyadh; b) how policy transfer issues are manifest in current decision making and c) the expectations that key stakeholders have for current and future projects.

These insights will be synthesised into a set of potential scenarios to test in the Riyadh microsimulation Model, subjecting some of the tenets of the policy transfer literature to a direct test and, similarly, some of the assumptions currently being made about solutions to Riyadh's transportation issues.

The researcher met several policy and decision makers, and each interviewee was chosen based on specific criteria, including their occupation, influence and the department in which they worked. These insights gave the research high levels of external validity, making the scenarios to be tested recognisable to research end users.

4.1.1 Future scenarios

All of this research is founded on the idea that city plans, visions and government expenditure do not exist in, or emerge from, a vacuum. Policy transfer is the theoretical backdrop (as explained in Chapter 3), against which it becomes possible to scrutinise the origins and modes of thought driving current levels of expenditure and the types of projects the government is funding in full. In other words, policy transfer provides a window on the implicit beliefs and assumptions which help explain the transport strategy Saudi Arabia is currently pursuing.

On a fundamental level, we can ask: why public transport? Indeed, why large-scale projects and not smaller-scale ones? The official plans and strategies provide only a partial insight into these underlying questions.

The next step is to deepen the analysis by interviewing key transport stakeholders in person. In this way, some of the tenets – as mentioned earlier – of the policy transfer literature can be directly tested (for example, is policy transfer manifest in Saudi Arabia?). Moreover, not only are the cultural and societal contexts of Riyadh unique, but so is the funding situation. Compared with many nations and cities, finance is less of an issue.

With this restriction removed, or at least lessened considerably, and a wide variety of different options potentially available, which solution should be chosen, and why? The analysis reported in this chapter provides valuable insight. Building on this is the development/synthesis of a set of possible future scenarios to test in the Strategic Microsimulation Model for Riyadh City Core (SMM). These represent the expectations of key Saudi Arabian transport stakeholders. Recreating them in a microsimulation environment will subject prevailing modes of thought, expectations and policies that may have transferred from elsewhere, to a direct test.

4.2 Strategies and decision making for transportation in Riyadh

Saudi Arabia is, in many ways, traditional in its culture and society. In view of this ethos, the socio-political milieu and need for economic progress, the monarchy chose to stick with Islam as the basis of the state, but also introduced new elements of governance, technology and infrastructure for economic welfare and educational advancement. This includes a thriving new university sector and strong support for a private sector (Muddassir Quamar, 2015).

In a sense, then, Saudi Arabia combines a conservative approach to society and the state with a modern stance on globalisation in terms of progressive development. Transportation, and its implementation in Saudi Arabia, is one of these features, putting the national transport system in a unique situation, as explained in Chapters 2 and 3.

On one hand, the decision makers involved in developing transportation projects across Saudi Arabia have full autonomy in dealing with such projects, including the often bold use of new technology and best practice approaches from elsewhere in the world. On the other hand, the higher levels of government, specifically the Ministers' Council and the Royal Court, oversee these approaches, to ensure that the potentially conflicting aspects of globalisation and Islam are resolved in ways that suit Saudi culture and governance.

A good example of this is that new trains typically incorporate the latest technology and high-quality engineering, provided by well-established (usually Western) providers, but they also contain family sections to maintain the privacy of occupants, alongside similar sections for the exclusive use of women travellers; consistent with local cultural norms. Another interesting feature is the provision of first-class facilities on ostensibly mass-transit facilities. This too reflects a specific cultural and societal norm. Measures like this ensure, in a very practical way, that new developments of benefit to Saudi society do not conflict with the religious and traditional pillars underpinning it (and which are described in more detail in Chapters 2 and 3).

Decision makers the world over face the same question of how to proceed with infrastructure upgrades. The situation and context in Saudi Arabia introduce a range of further very interesting factors which an increasing number of other nations are likely to face in future. In the Middle East and North African (MENA) region, several public transport projects have had to confront similar cultural and societal challenges (as explained in Chapters 2 and 3), not only to meet the development goals of various master plans (UITP, 2014), but also to fit into a distinct cultural and religious background.

The need to confront these issues is universal. The challenges of a car-based transport model are felt acutely in Saudi Arabia, as they are elsewhere, so designing alternatives that are suitable for this cultural and societal background cannot be avoided. Recognising this need, in July 2013 the Council of Ministers of Saudi Arabia approved the creation of the Public Transport Authority (PTA), with the aim of regulating public transport services, overseeing them, providing a good level of service at an appropriate cost, and encouraging investment in the system, in line with the objectives of improving economic and social development in the kingdom (UITP, 2014).

4.2.1 Overarching transport strategy

At the highest level, the Ministry of Transport has prepared a national strategy for

achieving the Saudi government's transportation goals. These goals are to:

- Develop the transport network across the kingdom
- Enhance the quality of existing networks
- Deal with new transport projects
- Make arrangements with other ministries in terms of transport needs and agreements
- Represent the kingdom in terms of transport, for example at international conferences and conventions (MOT, 2016)

Instrumental to achieving these transportation goals is a greater role for public transport within the kingdom. The Ministry of Transport undertook a study which resulted in the establishment of the Public Transport Authority (PTA) (see Table 4.2) to look at transportation across and between cities to explore what its role could be. Nevertheless, the ministry supervises and provides the appropriate level of quality and funding, and encourages investment in line with the kingdom's economic and social development goals.

National policies and plans are reflected in the case of Riyadh. The ADA has prepared a master plan for Riyadh (MEDSTAR) – as discussed in Chapter 3), which casts forward in time in terms of urban growth, land use, and environmental aspects. Riyadh has ambitious goals which are outlined in its master plan. Key among these is the need and expectation that Riyadh should accommodate a population of 10 million by 2020. Doing this requires a robust transport system and the assistance of the MOT to achieve the development goals for transportation in Saudi Arabia.

4.2.2 Transport policies and plans in Riyadh

Saudi Arabia is fortunate (and unique), in having access to very high levels of funding for strategic transport infrastructure projects. In Riyadh alone, there are no fewer than 4,821 such projects with a total value of SAR 509 billion to be implemented during

2016/17. Of these, 479 are transport projects valued at a total cost of SR 128 billion, or 33% of total infrastructure spending (ADA, 2015). By far the largest and most prestigious project, however, is the King Abdulaziz Transport Project, which includes the Riyadh Metro and buses scheme which is currently in its first stage with a total budget of SR 37,827 million.

Even this amount is just 9.6 % of the completed project until March 2015. The second-stage cost has a budget of SR 22,282 million, or 9.5% of the completed project (estimated completion date December 2018). The third stage is estimated to cost SR 29.592 million (ADA, 2015). This project will serve the city in terms of public transportation and will include the Riyadh Metro as well as buses. It's one of several potential future transport scenarios for the Saudi capital. Other solutions are available, and in order to achieve research objective number three (To generate and validate future Riyadh transport scenarios with key stakeholders and transport departments from the stakeholder interviews), semi-structured interviews were conducted.

The following sections present the interview methodology and findings before moving on to present an overview of the results in the form of four future scenarios to be tested.

4.3 Methodology

In order to develop the design of semi-structure interviews, the research has set the purpose of this study as flows;

- Gather institutional knowledge on traffic congestion and its mitigation
- Examine the extent to which the aspects of policy transfer theory are manifest in Riyadh's current transport planning practice
- Receive feedback on this research's findings from industry stakeholders

A semi-structured interview method was adopted. The main topic areas to be explored with interviewees can be summarised as:

- Congestion causes
- Policy transfer
- Barriers to change
- Land use and urban sprawl

The following section represents the design of the interviews and its themes:

4.3.1 Design

The interviewer met the stakeholders at their places of work and used a defined interview protocol (see Appendix D) to guide the discussion. The participants were made up of three groups spanning the main levels of the Riyadh transport policy hierarchy (as listed in Figure 4.1), where the highest level is the executive manager, such as the Chief Executive of the Public Transport Authority, the second level comprised department directors such as the Urban Planning Manager at Arriyadh Development Authority (ADA), and the third level was made up of managers or specialists in their department, such as the Manager of Safety and Roads Services at the Ministry of Transportation.

The interviews were recorded, transcribed and analysed using a theme-based content analysis methodology. The themes were as follows:

- Congestion sources
- Current solutions
- Best practice examples
- Provision of transport capacity management
- Land use policies and urban sprawl changing

- Limitation on growth
- Who owns the problem?
- How best to face the problem?
- Plans for engaging the community
- Main barriers to change
- Riyadh's future

4.3.2 Participants

Ten participants took part in the semi-structured interviews. They hold senior positions of authority in the ministries of Riyadh's transportation system (Table 4.1). It should be stressed once again that it is not routine or normal to have access to such senior transport stakeholders in Saudi Arabia, and choosing and meeting the right participants was a key challenge, since all of them were very busy. In the event, the necessary arrangements were made six months in advance, and official written approvals obtained. The researcher had talks with the supervisory team and the Saudi embassy in London before conducting the fieldwork trip. Table 1 shows the final list of interviewees, their occupations and the organisations they work for.

Table 4.1 List of interviewees, their occupations and organisations they work for

Name	Occupation	Organisation (Employer)
Eng. Tariq Qassi	Manager of Safety and Roads Services	Ministry of Transportation
Eng. Omran Elomran	Executive Principal Manager	Ministry of Transportation
Eng. Ahmad Esabeel	Urban Planning Manager	Arriyadh Development Authority (ADA)
Jalal Nafaleh	Chief Transport Planner	Arriyadh Development Authority (ADA)
Mohammed Mujeeballah Khan	Traffic Modeller	Arriyadh Development Authority (ADA)
Dr. Abdulazeez	Chief Executive	Public Transport Authority

Alauhali		
Rafat Brbour	Assistant Chief of Transport Department	Public Transport Authority
Eng. Khalaf Aldalbahi	Director of Design & Transportation Department	Riyadh Municipality
Eng. Yousef Al mutairi	President of Shumaisi Municipality	Riyadh Municipality
Dr Faisal Fahad	Former Director of Urban Planning Department	Riyadh Municipality

In addition, every organisation has a specific role to deal with traffic issues from its own perspective and authority (see Table 4.2). The Royal Court outlines the main tasks for the Ministers Council under Islamic guidance and refers to the religion's unique culture to create a suitable environment that falls within the Islamic agenda, for example including women's and families' privacy (see Section 1.1). Figure 4.1 shows the hierarchy of the responsible department dealing with the transport development process:

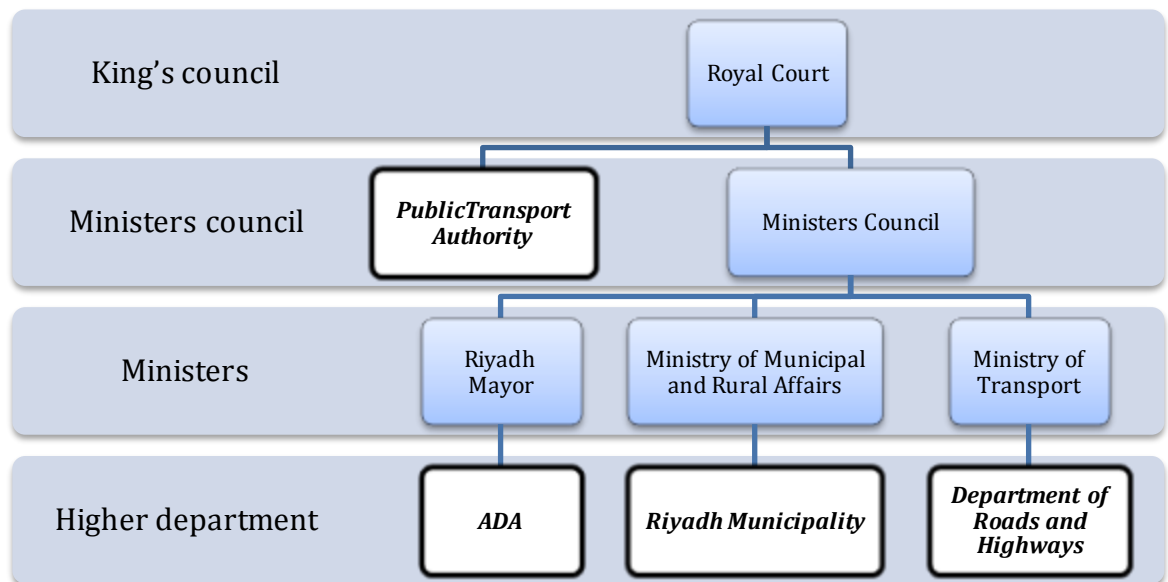


Figure 4.1 The hierarchy of transport authorisation in Riyadh City (black box refers to participants' departments). (Original: Author)

Each department understands its own responsibilities within the transport development process. Table 4.2 shows the organisations' responsibilities:

Table 4.2 Organisations and responsibilities

Ministry of Transport	Study, design, implementation and maintenance of roadworks;organises the development of road transport services within the kingdom, including highways and main roads inside and outside cities. Established in 1935.
Arriyadh Development Agency (ADA)	The High Commission for the Development of Arriyadh is the organisational, planning, executive and coordinating body responsible for the development of Riyadh. It was established on 20 June 1974 as a supreme authority chaired by HRH Governor of Riyadh (ADA, 2016).
Riyadh Municipality/ Riyadh Regional Council	Organisation and coordination of the town, according to the organisational chart approved by the competent authorities. Preserves the town's appearance and cleanliness, and establishes parks, squares and other public places. Determines the positions of street vendors, cars and vehicles. Regulation of transport procedure and wages in agreement with the relevant authorities. Established in 1943. (Riyadh Municipality, 2016). These actions fall under the Ministry of Rural and Municipal Affairs' umbrella.
Public Transport Authority (PTA)	The aim of this authority is to regulate public passenger transport services within and between cities, to supervise and provide an appropriate level of service and cost, and to encourage investment, in line with the kingdom's economic and social development targets. It was established in 2013.

4.3.3 Materials

Access to the stakeholders interviewed in this study is rarely granted. In this case, there were several initial formalities and conventions governing engagement with these senior people. These included letters of introduction, meeting minutes, outlines of dialogue and scholarship documents. In some cases, the researcher was required to provide a summary of the interview dialogue and what the aim of the interview was two or three weeks in advance. From this starting point, the researcher could then guide the participant into more focused areas of discussion in a way that was non-confrontational and in accordance with Saudi conventions.

The researcher began the interviews by summarising the size/scale of the traffic congestion problem, and why it was considered that this issue and its mitigation were worthy of serious consideration. In some cases, the stakeholder set out their vision at the beginning of the interview, (according to their status and custom), before the researcher skilfully steered them towards the specific questions (interview proper). The researcher followed the introduction with questions relating to the research aims and traffic congestion mitigation strategies following the main interview questions listed in Table 4.3 below:

Table 4.3 The main interview questions

	Question	Keywords	Research objective
1	<i>Do you think that Riyadh suffers from congestion?</i>	Congestion	<u>1</u>
2	<i>What are the possible causes of this congestion?</i>	Congestion	<u>1,5</u>
3	<i>What is Riyadh doing about the problem?</i>	Current plan	5
4	<i>What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?</i>	Examples	4
5	<i>What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?</i>	Predicting and providing solutions	7
6	<i>What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?</i>	Land use policies and urban sprawl	7
7	<i>Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?</i>	Limits of growth	7

8	<i>Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem?</i>	Congestion	<u>1</u>
9	<i>What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?</i>	Land use, urban sprawl	4
10	<i>What should be done to face the problem?</i>	Future strategies	3
11	<i>What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?</i>	Future strategies	3
12	<i>In your opinion, what do you think are the main barriers to change? What are the main barriers preventing people from relying on private cars as they do now?</i>	Policy transfer	6
13	<i>How do you see Riyadh looking in the future? What will life be like? How will people work here and enjoy leisure? What travel modes will dominate? What problems will be solved?</i>	Future strategies	3

4.3.4 Procedure

At the university, ethical approval and the trip Gantt chart (See appendix E) for interview was prepared and approved for the completion to conduct the interviews where it included all the formalities in this regard including supervisory approval, the main topics of the research questions and confirmation letters for the Saudi Arabia Royal embassy in London.

Due to the importance of the study, the Ministry of Higher Education was prepared for the fieldwork trip. As an initial step, the researcher was provided with a letter of introduction written by the Saudi Arabian Cultural Bureau in London in support of the research, and addressed to all the relevant departments working on transportation in Riyadh. The letter described the researcher's academic status, the importance of the study and its research contribution. As mentioned above, the researcher made advance contact with the relevant departments six months before the trip, via the Saudi embassy in London.

A summary of the thesis explaining its importance was submitted to the embassy's cultural department, and the decision makers showed great interest in the topic being studied. The field trip was scheduled for between 20th Nov 2015 and 20th Feb 2016, and each interviewee was visited within this timeframe, despite the difficulties the researcher faced in meeting the seniors/executives people in person. The researcher is a former vice-president of Riyadh municipality, and this contributed greatly in facilitating access to the decision makers, something which is not normally available to the general public. Conducting interviews with senior/executive people is a difficult task in comparison with other interviews, due to their social status and responsibilities. Thus, conducting the interviews was one of the biggest challenges of this research. Although the participants had been chosen carefully, there were some difficulties, such as staying within the set questions (in some cases the participant would get off the point to explain something else they thought was important, or to discuss their personal achievements), shortage of time and urgent work circumstances, which led to occasional temporary interruptions.

The researcher had to proceed flexibly (hence the semi-structured approach) and extract the required insights. The interviews were recorded via a voice recording application within the iOS system on an iPad tablet. This enabled the audio recording to be extracted and transcribed. The interview transcript was then translated from the original language (Arabic) into English.

4.4 Results

In general, the interviews corresponded to the theoretical background of the research, which was mentioned in chapters 1,2,3. The participants affirmed that the key solution to solving congestion problems in Riyadh is public transport where the officials place the greatest hopes on to change the current mode of transportation in Riyadh. This aspect (public transport), as mentioned above, is currently being built on the ground. Participants also confirmed that the issue of policy transfer is considered and they will develop plans/schemes to engage the community in the process of introducing new policies.

In addition, they said that the new services must be designed in line with the characteristics of the Saudi society to ensure the best results. And, in terms of congestion sources, the participants confirmed that there are 6 main causes of congestion in Riyadh, from the viewpoint of stakeholders are: 1) Poor planning, 2) lack of public transport, 3) large-scale projects, 4) free parking, 5) private car dependency and 6) social trips

However, the results were divided into two main sections. In Section 4.4.1, the descriptive analysis describes the main points of the interviewees' answers from the transcripts, grouped by question themes. Section 4.4.2 presents the results of the theme-based content analysis, and focuses on the main issues of future scenarios and policy transfer.

4.4.1 Descriptive analysis

The following tables summarise the main questions and answers for each aspect of the semi-structured interview:

4.4.1.1 Question 1: Do you think that Riyadh suffers from congestion?

All participants agreed in their responses to Question 1 (as shown in Table 4.4) that Riyadh's traffic problem is the main issue for all planners and decision makers. So 100% of interviewees said yes to the first question.

Table 4.4 Q1: Do you think that Riyadh suffers from congestion?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	YES
	Participant 2	YES
Arriyadh Development Agency (ADA)	Participant 3	YES
	Participant 4	YES
	Participant 5	YES
Public Transport Authority	Participant 6	YES
	Participant 7	YES
Riyadh Municipality	Participant 8	YES
	Participant 9	YES
	Participant 10	YES

4.4.1.2 Question 2: What are the possible causes of this congestion?

The interviewees said that Riyadh's traffic congestion was caused by six main factors, but particularly by a lack of public transport (PT). These causes are listed as follows and shown in Table 4.5:

- Poor planning
- Lack of public transport
- Large-scale projects which cause traffic to be diverted
- Parking, private car dependency
- Social trips

Table 4.5 Q2: What are the possible causes of this congestion?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	1. Poor planning in government departments, schools and universities 2. The lack of public transport
	Participant 2	1. Poor planning, ministries locations in the city centre 2. The establishment of large-scale projects and roadworks
Arriyadh Development Agency (ADA)	Participant 3	1. Lack of public parking 2. Commercial land use on the streets
	Participant 4	Work and school trips
	Participant 5	1. No alternative modes of transport 2. Lack of public transport 3. Land use
Public Transport Authority	Participant 6	1. Private car dependency 2. Lack of public transport 3. Peak times across various activities 4. Social trips 5. Current road works
	Participant 7	Rapid city growth
Riyadh Municipality	Participant 8	1. Lack of PT 2. Poor planning
	Participant 9	1. Private car dependency 2. Poor planning 3. Lack of PT

	Participant 10	1. Migration to the city 2. Lack of PT 3. Road parking and traffic police efficiency
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4.4.1.3 Question 3: What is Riyadh doing about the problem?

Riyadh City Council's transportation department has adopted a number of strategic approaches aimed at tackling the traffic problems shown in Table 4.6, including: the Riyadh Metro project, e-government services, which were launched in 2009 (ADA, 2015), implementation of Intelligent Transportation System ITS such as a traffic police system, fines and penalties, parking spaces, a park and ride facility, the Riyadh bus project, and re-planning specific areas of the city, including the Riyadh court, national museum and King Abdullah Financial District (KAJD).

Table 4.6 Q3: What is Riyadh doing about the problem?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	Metro project Starting to create e-government services Implementation of ITS
	Participant 2	There's obvious effort from all departments to study the problem and potential solutions
Arriyadh Development Agency (ADA)	Participant 3	Starting to use ITS Traffic police are enforcing strict fines and penalties Creating more parking spaces Replanning different parts of the city
	Participant 4	Developing PT Implementing traffic management systems
	Participant 5	Restudying road capacity, PT, traffic management, ITS

Public Transport Authority	Participant 6	Public transport Traffic management Road modification and development
	Participant 7	PT Traffic management
Riyadh Municipality	Participant 8	Developing the road network Cooperating with other transportation departments Associating with ITS
	Participant 9	PT Traffic management ITS
	Participant 10	PT Traffic management Road improvements

4.4.1.4 Question 4: What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Meanwhile, the comprehensive transport plan looked at meeting the city's existing and future transportation needs, keeping up to date with the systems of developed countries while taking into account the Saudi capital's continuous population growth. In this regard, Table 4.7 shows the key cities/countries for best transport performance, identified through in-depth interviewing. Equally, the majority of participants looked to the US for examples of best practice, particularly Los Angeles and Detroit. This is interesting given that the style of Riyadh's own road network has many similarities with that used in the US.

Table 4.7 Q4: What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	USA, Turkey, France, UK
	Participant 2	Malaysia, UK, Japan, USA
Arriyadh Development Agency (ADA)	Participant 3	Developed countries – particularly those with PT systems
	Participant 4	London
	Participant 5	All developed countries
Public Transport Authority	Participant 6	Singapore, London, Paris, North America, Australia
	Participant 7	UK, USA
Riyadh Municipality	Participant 8	All developed countries
	Participant 9	Los Angeles, Munch, Paris, Detroit, Dubai
	Participant 10	London, Japan, Washington, Frankfurt

4.4.1.5 Question 5: What is your view about transport capacity provision – should we keep ‘predicting and providing solutions, or is now the time to try and ‘manage demand’?

The provision of transport capacity should be well addressed in such cities. However, the interviewees mentioned (see Table 4.8) that their relevant departments should take immediate plans to help control and build up a more efficient, powerful transport system, for example through strict controls on private car use, commitment of land use, ITS systems, and updating road network regulations.

Table 4.8 Q5: What is your view on the provision of transport capacity – should we keep ‘predicting and providing solutions, or is now the time to try and ‘manage demand’?

Organisation	Participant	Answer
Ministry of	Participant 1	Saudi Arabia’s major cities must start their

Transportation		own public transport systems, as a matter of some urgency.
	Participant 2	I think demand for public transport will increase if there are strict controls on private car use,
Arriyadh Development Agency (ADA)	Participant 3	Demand for transport is increasing, and there must be solutions, namely: public transportation, traffic adjustments through the use of modern techniques, commitment of land use and its development.
	Participant 4	It's the right time for efficient demand management.
	Participant 5	Traffic procedures in place to make informed decisions, as well as having good traffic management measures to create an efficient transport system.
Public Transport Authority	Participant 6	Provide sufficient capacity for both private cars and public transport. Demand for public transport must be started now; it will cost more if there's a delay.
	Participant 7	All the previous answers. Public transport, land use obligation, ITS.
Riyadh Municipality	Participant 8	The municipality has a good plan to deal with capacity including: developing junctions, making adjustments for traffic lights, creating new roundabouts and simulation software
	Participant 9	Many studies and research have been conducted on road capacity and its capabilities so far.
	Participant 10	The Metro project has opened the door to all consultants to study the congestion impact and traffic demand management in Riyadh

4.4.1.6 Question 6: What is your point of view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

It has been said that Riyadh's physical shape should be replanned, and this modification is mainly required as a solution to the problems of the current transport system. The interviewees identified several key issues in terms of their duties and responsibilities as listed in Table 4.9, these can be clarified as follows:

- With other parts of city services
- Planning patterns
- Transit-oriented development (TOD)
- Horizontal growth of the city
- Housing policy

Table 4.9 Q6 What is your point of view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	Yes, it is very important
	Participant 2	Yes, there is an urgent need to get unused lands inside the city boundaries, and to connect them with other aspects of city services.
Arriyadh Development Agency (ADA)	Participant 3	Yes. And we have to get out of the grid network patterns of planning, which have led to an increase in private cars.
	Participant 4	Yes, Riyadh should consider transit- oriented development TOD.
	Participant 5	Riyadh has a structural plan, zoning etc., the only thing is to implement this on ground. Transport and land use will be integrated by doing so.
Public Transport Authority	Participant 6	Yes, we have to change our cities from two aspects: first, limitation of horizontal growth. Second, we should consider our housing philosophy and what we are need exactly in our houses elements and content.
	Participant 7	Yes
Riyadh	Participant 8	Yes. Land use and transportation should be integrated, and take into account growth limit

Municipality		restrictions.
	Participant 9	The strategic master plan should deal with these aspects.
	Participant 10	Yes of course

4.4.1.7 Question 7: Are we reaching the limits of growth or is the vision to enable more space for residents and commercial development?

Riyadh is a metropolitan city, and its huge population has required other strategies with urban growth and internal migration. The interviewees referred in Table 4.10 to deal with urban growth as a matter of some urgency, and the strategies mentioned for dealing with this include:

- Creating more suburbs
- Unused land
- Building regulations
- Economic developments

Table 4.10 Q7: Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	Yes. it's time to create more suburbs and encourage sustainable development.
	Participant 2	In some parts of city, yes, we have reached our growth limits. On other hand, as I said, there is a lot of unused land which should be developed.
Arriyadh Development Agency (ADA)	Participant 3	Yes, we have reached our growth limits and we are working to create new limits every five years. And progress has been made in terms of developing on unused land across the city.
	Participant 4	We should revise building regulations
	Participant 5	The Riyadh master plan takes to the growth in terms of residential neighbourhoods. And it

		will improve at an accelerating rate.
Public Transport Authority	Participant 6	Commercial and economic development is the core thing in terms of providing jobs and improving the quality of life. We should consider consumer activities, and productive activities. Thus, we should increase the available space for productive activities and so on.
	Participant 7	No limits on growth, management is the key
Riyadh Municipality	Participant 8	The rapid growth of Riyadh is a big challenge and the municipality has considered this growth, and its impact on land use
	Participant 9	We should consider our building licence and its efficiency
	Participant 10	The strategic master plan has been developed every five years

4.4.1.8 Question 8: Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem to deal with?

In terms of responsibility for Riyadh's traffic problems, all interviewees said that all the transport departments and authorities, especially Riyadh Municipality, share responsibility for owning traffic congestion problems. Table 4.11 below shows these answers in details:

Table 4.11 Q8: Who owns the problem? Is it the Dept. for Transport's problem to solve? The building licence people? Or is it the user's problem to deal with?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	It is obvious that the problem is complicated between both the governmental aspects and social responsibility.
	Participant 2	The municipality: due to the building licence Road users: because they have to obey the regulations

Arriyadh Development Agency (ADA)	Participant 3	All departments you have listed own the problem and so must find solutions
	Participant 4	All of them
	Participant 5	All of them
Public Transport Authority	Participant 6	These departments are in charge collectively
	Participant 7	User problems should be solved by MOT, ADA and the municipality
Riyadh Municipality	Participant 8	All departments
	Participant 9	All of them
	Participant 10	I think the municipality is largely responsible for the problem

4.4.1.9 Question 9: What should be done to face the problem?

The key solutions for congestion problems were specified as listed in Table 4.12, including reducing private car use and implementing an efficient public transport system. Specifically, they say that knowledge improvement will support new traffic technologies. The interviewees also identified main strategies for dealing with traffic problems, as follows:

Reduce private car use by:

- Creating a high committee for traffic problems
- Establishing a research centre
- Estimating the impact
- Having an efficient PT system

Table 4.12 Q9: What should be done to deal with the problem?

Organisation	Participant	Answer
Ministry of	Participant 1	Thinking about reducing private car use

Transportation	Participant 2	We should encourage our people and put more effort into solving the problem Create a high committee for traffic problems
Arriyadh Development Agency (ADA)	Participant 3	Cooperating with other departments Creating a research centre to study these problems and come up with solutions
	Participant 4	Good planning, more research
	Participant 5	Working to estimate the impact and prioritise that impact Cooperating with other departments to create a long-term strategy
Public Transport Authority	Participant 6	Good forward planning
	Participant 7	Having an efficient public transport system Encouraging people to use it
Riyadh Municipality	Participant 8	Shifting people to use public transport More consideration about land use and the shape of the road network
	Participant 9	Creating a transport strategy Considering other cases across the world
	Participant 10	As discussed previously, all departments are involved in the problems and must find a solution together

4.4.1.10 Question 10: What is your plan for engaging the community, or what is your alternative plan in the case not engaging them?

As mentioned in Chapter 2 and elsewhere, Riyadh's situation is unique in terms of privacy and culture. However, engaging the community in transportation issues can be encouraged by raising awareness and stimulating discussion of the issues. Such dialogue is valuable key step in developing an appropriate transport system, as shown in Table 4.13.

Table 4.13 Q10: What is your plan for engaging the community, or what is your alternative plan in the case not engaging them?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	One of the main ideas for shifting people from private car use to PT (advertising, encouragement, free tickets and look at other cases worldwide).
	Participant 2	Engaging people to discuss the issues is one of the key factors, especially those with good experience in that field.
Arriyadh Development Agency (ADA)	Participant 3	By showcasing public transport plans and projects and listening to feedback and ideas.
	Participant 4	Everyone must participate
	Participant 5	By holding an annual meeting and conferences to engage people and encourage them to participate.
Public Transport Authority	Participant 6	One of the objectives of the Public Transportation Authority is to raise awareness of the importance of PT and its benefits to society.
	Participant 7	Without community engagement, there is no solution
Riyadh Municipality	Participant 8	It is very important and the municipality must raise awareness of public transport
	Participant 9	We must consider our culture and privacy needs and look at other examples to find perfect one that would apply to our case.
	Participant 10	By changing land use and telling people that transport is an important, attractive way of replacing and reducing private car use.

4.4.1.11 Question 11: In your opinion, what do you think are the main barriers to change? What are the main barriers preventing people from relying on private cars as they do now?

It has been found (see Table 4.14) that one of the main barriers to using Riyadh's public transport is the low petrol prices that make public transport an undesirable alternative to the private car. Private vehicles are a highly cost-effective means of transportation within the region, and will remain so for years to come. Alongside this, there are the restrictions of Islamic religion and culture on the movement of women. This results in the social exclusion of Saudi women, causing them to be largely dependent on male relatives to drive them, or, alternatively, they rely on private drivers. Therefore, inclusive public transport use will be of great benefit to Riyadh's traffic, economy, society and environment.

Table 4.14 Q11: In your opinion, what do you think are the main barriers to change? What are the main barriers preventing people from relying on private cars as they do now?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	There is no strict roles on the drivers Easy to get a private car and driving licence
	Participant 2	There is no PT Destinations are too far away from each other
Arriyadh Development Agency (ADA)	Participant 3	No effective public transport system
	Participant 4	The main reason is the absence of public and school transport
	Participant 5	Lack of PT and low petrol prices
Public Transport Authority	Participant 6	Private car use will still be attractive even in communities with public transport, but change starts from two points: 1. Policy change on private car use 2. Motivate environmental conservation and the national economy
	Participant 7	No practical experience
Riyadh	Participant 8	Shifting people to use public transport

Municipality	Participant 9	Privacy, culture and low petrol prices
	Participant 10	Changing policy on private car and road user is a key barrier

4.4.1.12 Question 12: From your point of view how do you see Riyadh looking in the future? What will life be like? How will people work and enjoy leisure? What travel modes will dominate? What problems will be solved?

In Table 4.15, the interviewees say they believe Riyadh to be a rapidly growing and developing city. And if public transport policies or pricing policies were introduced here, this would force travel behaviour to change. They also imagine that Riyadh will be one of the capital cities in the world within the next decade.

Table 4.15 Q12: From your point of view, how do you see Riyadh looking in the future? What will life be like? How will people work and enjoy leisure? What travel modes will dominate? What problems will be solved?

Organisation	Participant	Answer
Ministry of Transportation	Participant 1	New projects such as the Riyadh Metro and more public transport will absolutely reduce congestion. Transport modes will become easier and more environmentally friendly.
	Participant 2	I think Riyadh will become one of the world's most developed capital cities. Public transport facilities will enhance the economy and create easy connections between the different parts of the city.
Arriyadh Development Agency (ADA)	Participant 3	I think Riyadh is going to be a developed city once it's implemented its strategic plans and projects. Life will become easier in terms of business, social activities and entertainment.
	Participant 4	Riyadh will be the jewel of the Middle East!
	Participant 5	Traffic future will be attracted with the transportation of public this will be more participate public opinion.
Public Transport Authority	Participant 6	Riyadh is the one of the biggest cities in the world, so it has a rapidly ongoing population. There are continuous studies and research into developing solutions like other capital cities worldwide. And

		we should take into account newest methods and technology.
	Participant 7	Riyadh means paradise in Arabic. It should be like its name!
Riyadh Municipality	Participant 8	The municipality is working on a lot of new projects that will provide great solutions, as mentioned before
	Participant 9	I think Riyadh is going to be a capital city with an easy life that should take its place in the developed world phase
	Participant 10	Easy travel, environmentally friendly and a strong economy

4.4.2 Theme-based analysis



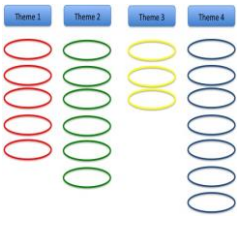
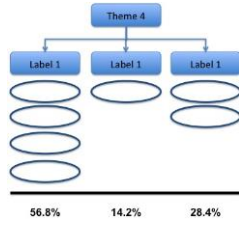
The analysis approach adopted in this research was the Thematic analysis which is one of the methods used in the analysis of qualitative data, where the researcher organize and put data in specific topics or categories, and then explain and interpret them analytically to find the answer to the research question. The way that analysing the interviews was by focusing on the commonalities between the data, four tasks have been done to complete the analysis as presented as follows:

- Task 1: Transcribing the interview from the audio device to be written and translated (if it were in Arabic)
- Task 2: Search for main topics/categories in the interview answers
- Task 3: Review potential theme answers to be labelled in the following task
- Task 4: Identify and label themes according to the research question to be grouped and diverted as pie charts with other answers for the same theme.

According to these tasks, the final output is to convert all of these numbers into one label, and then each label is calculated separately to give the general ratio of the final answer. For example, Theme 4 (congestion solutions) This theme was conducted from Questions 2, 3, 4 and 11 and the ratios of the pie charts were calculated according to the

number of responses to this solution. Where there were about 50 responses focused on public transport, 45 responses focused on private car reduction, and 34 focused on re-planning land use. However, the following table 4.16 illustrate the main tasks for the thematic analysis and how were the figures for the pie charts derived:

Table 4.16 the tasks involved in the thematic analysis (Original; Author)

Task 1	Task 2	Task 3	Task 4
Transcribing the interview	Search for main topics/categories	Review potential theme answers	Identify and label themes according to the research question
			

However, there were three main conclusions as to what was required to achieve the desired transport development in Riyadh. These themes are listed in Table 4.17 below:

Table 4.17 Main themes resulting from the interviews

	Main themes	Elements
1	Congestion sources	Poor planning. Lack of public transport. Large-scale projects. Parking. Private car dependency. Social trips. Related departments. Road users.
2	Policy transfer plan	Reduce private cars. Encourage people. Estimate the impact. Efficient PT system. Replan land use. Spread awareness. Land use improvement, annual meeting and discussion.
3	Barriers to change	Roles, PT, private car use and city attractions
4	Land use policies and urban sprawl changing	Developing a master plan, create new suburbs, unused land, building regulations, TOD

5	Solution	Public transport, reduce private car use, replan land use, TDM
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The following sections explore each of these themes in more detail.

4.4.2.1 Congestion sources

Congestion causes themes were extracted from Questions 1 and 7. Congestion causes themes were extracted from Questions 1 and 7. The proportions of these causes was diverted by focusing on the commonalities between the data as described above (see section 4.4.2). The causes of congestion in Riyadh, from the view point of stakeholders, as shown in Figure 4.2, include: poor planning, a lack of public transport, large-scale projects, parking, private car dependency and social trips.

The lack of a good PT system was 26%, making it the highest cause of traffic jams, and it has a direct influence on private car use. So it is clearly a factor behind the Riyadh Metro project. Furthermore, planning patterns, including parking and land use, have been increasing traffic jams. The main themes resulting from the analysis of the interviews are seen below in Figure 4.2:

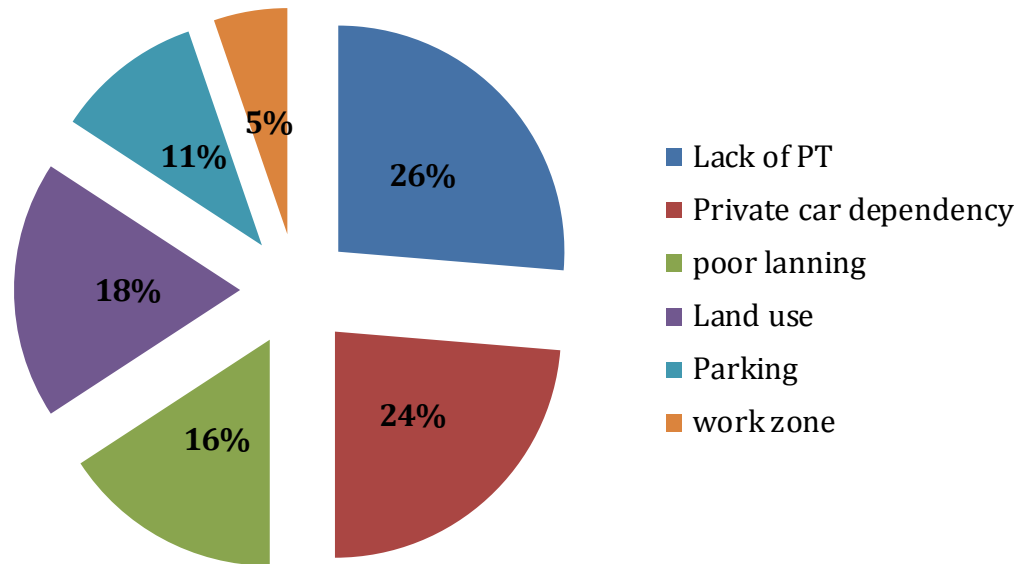


Figure 4.2 Main causes of congestion in Riyadh

4.4.2.2 Policy transfer

As mentioned in Chapter 3, Riyadh has witnessed a critical change in policy transfer regarding urban issues, in terms of the master plans and transport methods. There are three key features of policy transfer that seem to be manifest in the interview data as shown in Figure 4.3. These features mainly stem from Questions 6 and 8. The first of these features is managing traffic demand.

This is a key aspect of policy transfer for identifying future congestion. Since decision makers and senior officials mandating transportation planning divisions hold responsibility for maintaining, continuing and coordinating the planning process in all its premises. A travel demand planning process should be used in addressing the Riyadh's transportation needs and to support planners in making decisions.

The participants mentioned that Riyadh needs to do more research and take advantage of international expertise, specialist elites and typology, especially from the West (see Questions 7, 8 and 9). As defined in Chapter 3, a 'specialist elite' is considered one of the most important aspects policy transfer.

Interviewee Participant 6 says, "Providing sufficient capacity for both private car and public transport and traffic demand of transport must be started now, it will be with higher cost, for as long as it's delayed." In the same vein, another participant, Participant 2 says, "Yes, there is an extreme need to get unused land inside the city's boundary and work on how to connect them with other parts of city services", this opinion is shared by yet another participant, Participant 4.

The second feature of policy transfer is the land use and urban sprawl policies. All participants agreed that Riyadh's physical shape needs to change. Interestingly, Participant 1, Participant 2 and Participant 7 say a big 'yes' with no actual plan. In contrast, Participant 6 says, "Yes, we have to change our cities from two aspects: First, limiting the horizontal growth. Second, we have to consider our housing philosophy and what we need exactly in our houses' elements and content". Participant 3 refers to planning patterns, stating, "Yes, and we have to get out of the grid network pattern of planning, which has led to an increase in private cars". As mentioned in Chapter 3, the integration of land use and transport systems poses a major challenge for the policy transfer process if Riyadh is to protect itself from the past consequences of the Doxiadis master plan.

The third aspect of policy transfer is how to encourage the community to get involved in new policies. Dolowitz & Marsh's policy transfer framework model (see Table 3.1), which has been applied to Riyadh, argues that this aspect is an obstacle to the transfer of policies in terms of adapting people with new projects. Participants emphasised that relevant departments must take into account awareness raising of public transport use. One interesting feature is the extent to which this aspect of policy transfer shifts from private car to public transport as one progressed further up the Riyadh stakeholder hierarchy.

Participant 6 addressing this aspect directly, describes the issue thus, "One of the objectives of the public transportation authority is to spread awareness of the

importance of PT and its benefits to society”, which is quite different to the opinion of Participant 3 who believes it can be carried out, “By having annual meetings and conferences to engage people and encourage them to participate”. These differences seem to arise from the authorities’ responsibilities and their access to development progress.

On the other hand, privacy and Saudi culture are among the main issues according to Participant 9, who states, “We have to take into account our culture and need for privacy, and look to other examples and the perfect one that would be applicable to our case”. However, policy transfer plans proportions have been diverted as described above (see section 4.4.2) by focusing on the main plans/ commonalities between the data and then reviewing the potential theme answers. Figure 4.3 summarises the policy transfer plans from the stakeholders’ point of view.

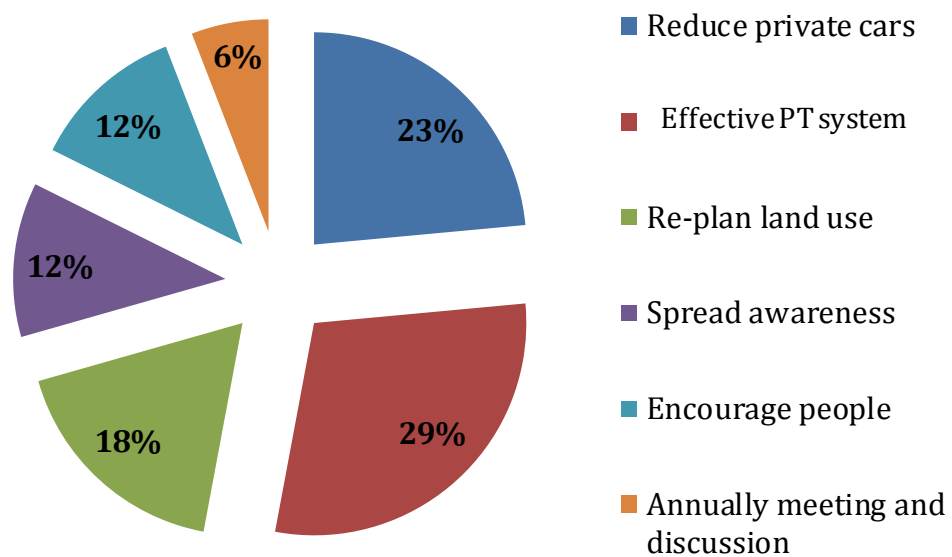


Figure 4.3 Policy transfer plans

4.4.2.3 Barriers to change

The main barriers to change were drawn from Questions 9 and 10 are shown in Figure 4.4. These barriers referred to by the participants in the interviews directly through the interview dialogue, which have been diverted after the interviews transcription, the analysis revealed that there are some barriers mentioned in the interview transcripts more than others as shown in figure 4.4.

To influence people and encourage them to use public transport rather than their own cars, the factors affecting this process first need to be ascertained. Finding out the reasons is a big part of the solution that would contribute to the public transport system's effectiveness. This, of course, is a very large area of research in its own right, and we are dealing here with the participants' subjective views.

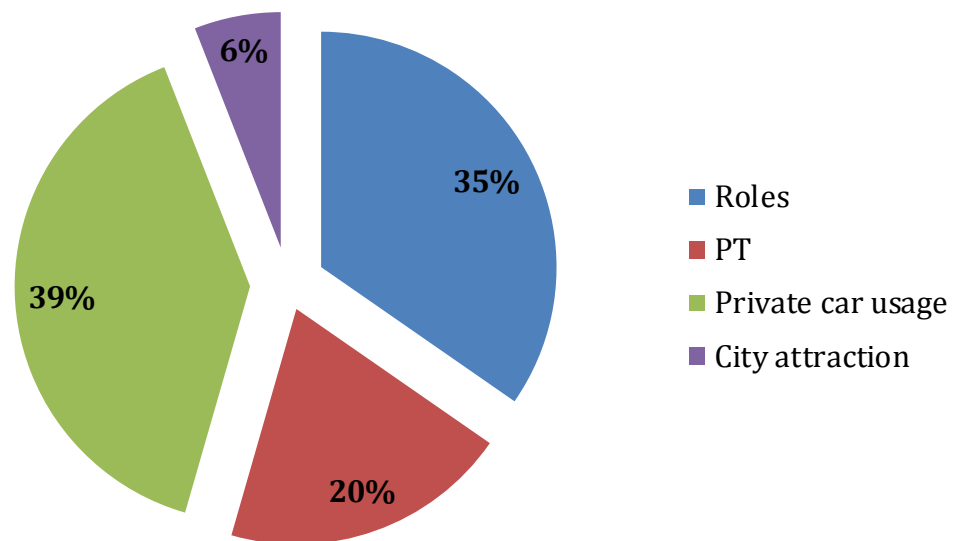


Figure 4.4 Barriers to change

To influence people and encourage them to use public transport rather than private cars, the factors affecting this process need to be ascertained first. The answers in this regard were different; the reason for these different views was down to the individual interviewee's position, practice and responsibilities. For example, Participant 6 describes the main barriers as: "Private car usage will still be attractive, even in communities that contain public transport. The change starts from two points: Change

in the private car policy's usage and motivate Environmental Preservation and the national economy".

Meanwhile Participant 5 does not allude to these reasons, he describes the most important factors as being a lack of similar experiences, which he refers to as "No practical experience, due to the lack of PT" (described in Chapter 4).

Other participants focused on the lack of PT, except Participant 9, who stressed that Saudi culture has to be considered a major issue. He says that "privacy and culture" are the main barriers to change. In a parallel line, Participant 10, 'Changing policies on private car and road users is the main barrier'.

4.4.2.4 Land use and urban sprawl changing

Figure 4.5 illustrates this theme, which was extracted from Question 5 and via the tasks presented in table 4.16. The same thematic analysis described in section 4.4.2 has been applied to this theme. The current and future patterns of development are a primary factor in route location for any new public transport system. The proposed development plan identifies current and future land uses and densities of development that will need to be reinforced by good transportation services. The following chart illustrates the main aspects of urban sprawl and change of land use:

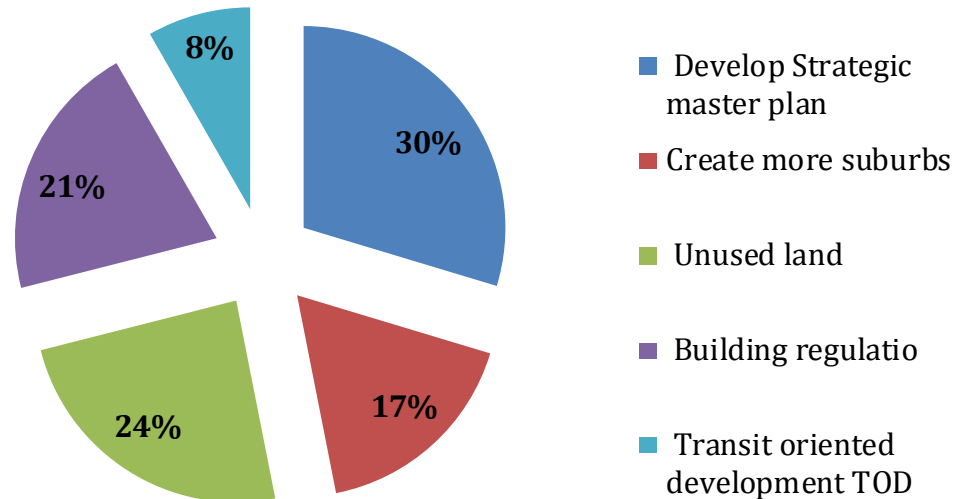


Figure 4.5 Land use and changing urban sprawl

Limited growth and urban sprawl must be considered within the context of five factors including: creating more suburbs, unused land, building regulations, economic development and management. Participant 3 confirmed that Riyadh has reached the limit of its growth and said, "Yes, we have reached growth limits and we are working to create new limits every five years. And there is development on the unused land within the city". Participant 10 agreed that the master plan needs to be improved.

Another view came from Participant 8, who said, "Yes, Riyadh should consider (TOD)". According to the Transit Oriented Development Institute (2002), this is an exciting, fast-growing trend for creating vibrant, liveable, sustainable communities. It's the creation of compact, walkable, mixed-use communities centred around high-quality train systems. This makes it possible to enjoy lower levels of stress without complete car dependency.

4.4.2.5 Congestion solutions

The interviews affirmed many research findings, such as those to do with: congestion sources, current solutions, land use policies and Riyadh's future. There is, however, one theme that continually surfaced during the interviews which forms the foundations for

the final chapter: there is no ‘silver bullet’ for solving the problem of traffic congestion. It is, as the overarching theoretical stance of this thesis highlights, a systems problem - and urban planning is the method by which this complexity is mediated and resolved. This seems to be recognised, tacitly or otherwise, by all the key stakeholders. This theme was conducted from Questions 2, 3, 4 and 11. And it was identified based on patterns in the interviewee visions. However, each department its own perspective on dealing with traffic jam issues. This study found that the main strategic solutions were reliant on the following factors:

- Public transport
- Strategies for reducing private car use
- Replanning land use

The results of thematic analysis (which has been described in section 4.4.2) will be presented in the following Figure 4.6

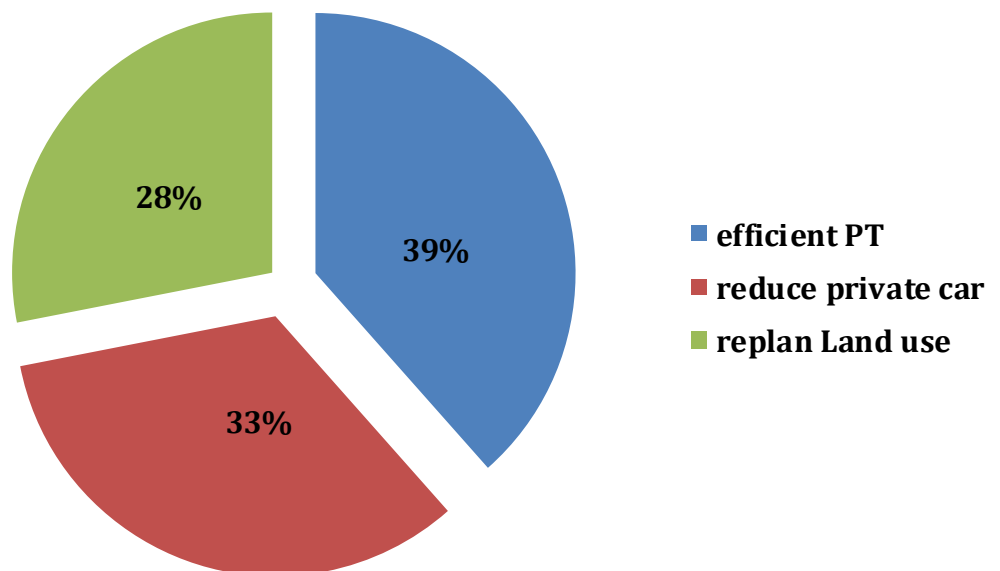


Figure 4.6 Congestion solution from the interviewees' point of view

Subsequently, these strategies will be examined in comparison with the current situation in the same microsimulation test bed. The same set of network performance indicators

will be extracted to help understand how these strategies will provide a sustainable development and relieve/prevent traffic jams in Riyadh. In amongst the wide range of possible strategies, these are the ones that Riyadh's main stakeholders feel to be most appropriate. Further strategies, which take into account Riyadh's unique cultural and social aspects, will be designed based on the results of these comparisons. The following sections of this study investigate each strategy's implementation at the highest level, while determining the main policy transfer issues. The following sections explore the future scenarios and their implementation in Riyadh.

4.5 Extracted scenarios and their implementation

The results of the stakeholder interviews have been synthesised into four main future scenarios. These are extracted from the analysis (Section 2 and 3), and will be tested in the Riyadh Strategic Microsimulation Model (SMM); these strategies will be described in outline form in the following sections. They represent a set of broad interventions. The specifics of their implementation within the microsimulation model will be outlined in Chapters 6, 7 and 8.

4.5.1 Scenario 1: Do nothing

Obviously, car demand will increase, which will inevitably overload the road network if no action is taken. As a result, congestion will increase. This, in simple terms, is the 'do nothing' option: the baseline. Population and car use continue to expand along their forecasted trajectories with no corresponding change in the city's transport facilities.

4.5.2 Scenario 2: Public transportation policy

The estimation report provided by ADA in preparation for the Riyadh public transport project (which includes both the Riyadh Metro and buses) summarised the results of the analysis of future demand for the subway lines planned for Riyadh. The metro, along

with the bus system (which includes conventional lines and Bus Rapid Transit BRT lines) will provide the city's residents with an efficient and high-quality solution for their journeys. This new system represents a radical change in the city's public transport offering, which is currently limited to a small number of lines that, in many cases, are considered as an experimental platform for estimating the demand for public transport once the new lines are up and running. It's an exercise in which some uncertainties have to be assumed.

Even when using the best techniques and available information, it can be difficult to predict peoples' reactions to future transport modes, which can be completely different from the actual ones. Having said that, the 'aspiration' is clear:

"The project will be of great benefit to Riyadh traffic, economy, society and environment. Moreover, it will provide the city with a giant public transport system to meet its existing and future needs". (ADA, 2015)

Today, Riyadh has become as a huge workshop due to the metro project (as shown in Figures 4.7, 4.8), which is underway 24 hours a day at the time of writing.



Figure 4.7 Riyadh Metro construction work (ADA, 2017)



Figure 4.8 Riyadh Metro construction work (ADA, 2017)

4.5.3 Scenario 3: Reduce private car dependency

According to the Victoria Transport Policy Institute (2017). This policy is the combination of several techniques aimed at reducing private car usage within the city which has been applied over the world in order to encourage people to use an alternative method of travelling rather than their own cars.

In order to reduce private car dependency, the government is using (or planning to use) several techniques linked directly with PT ridership. These include fuel taxation, door-to-door timings, acceptability licence limitation and other measures. Many techniques will probably depend on the demographic and culture status of the intended 'target demographic'. The following sections describe the main strategies that would be applicable according to stakeholder perspectives.

4.5.3.1 Road pricing

Road pricing is considered a potentially effective measure for reducing traffic congestion. This section aims to identify and compare the detailed set of implementation factors for six cases in which road pricing was implemented as a policy to reduce traffic congestion in : Singapore, London, Stockholm, Norwegian cities, Hong Kong and Edinburgh. Policy implementation lessons are formulated to help local and national authorities considering implementing road pricing.

Previous research (H. Gudmundssona et al., 2009) has successfully identified the most prominent factors which reduce congestion. These were related to political and public support. Consequently, authorities aiming to implement road pricing also need to take many case-specific factors into account in the implementation process. Furthermore, the six cases show that policy implementation will only succeed when many factors combine to contribute positively to the process, and that explains why it is such a precarious endeavour.

4.5.3.2 Parking charges

The overall impact of the public transport network on general traffic is shown in the following map. The PT flows (green bars) are similar or higher in some corridors than those corresponding to private transport (red bars). Figure 4.9 shows the proposed plan for parking charges in Riyadh.

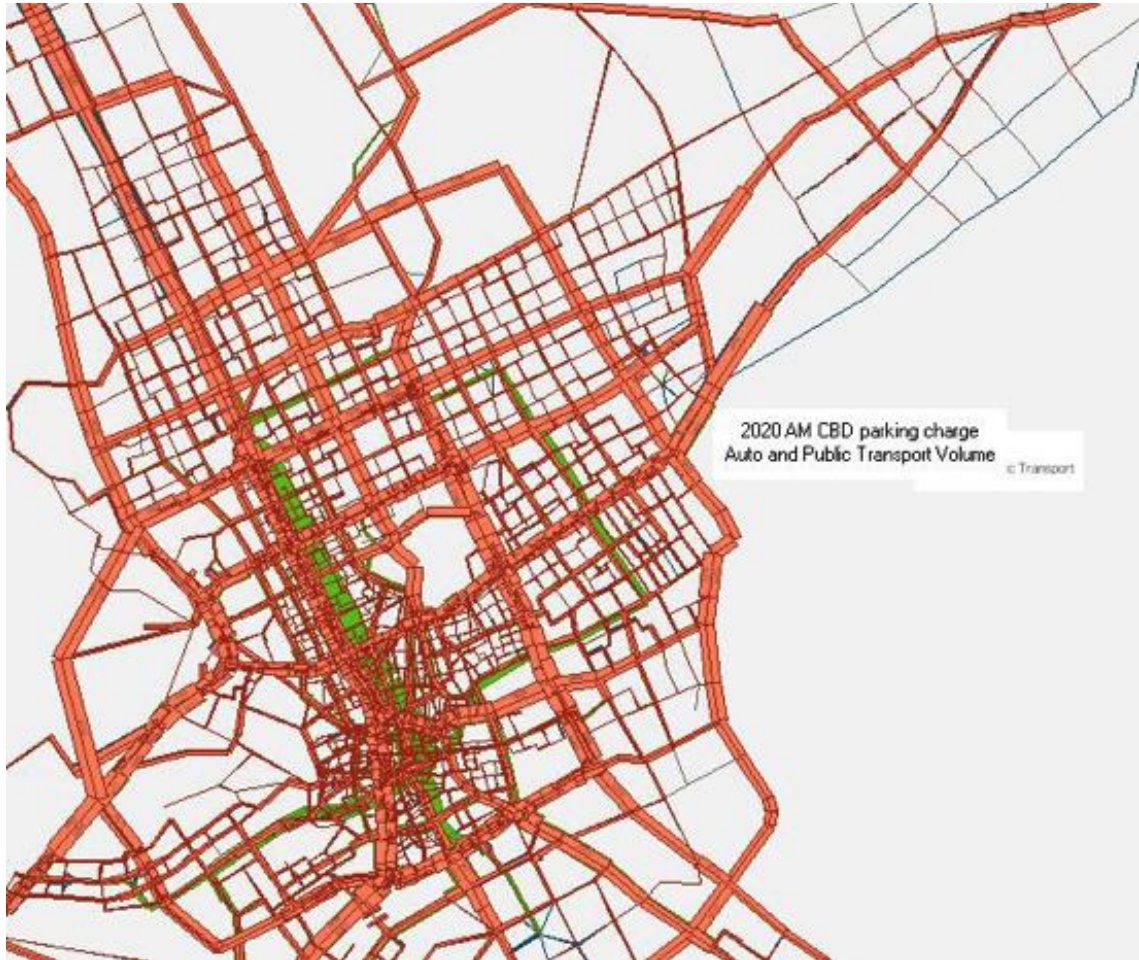


Figure 4.9 Parking charges, AM period, 2020 (Source: ADA, 2016)

4.5.3.3 Transport Demand Management (TDM)

Transportation demand management, traffic demand management or travel demand management (all TDM) is the application of strategies and policies to reduce travel demand, or to redistribute it in space or in time. According to the Victoria Transport Policy Institute (2014), (TDM) is a general term for strategies which result in a more

efficient use of transportation resources. This encyclopaedia is a comprehensive source of information about innovative management solutions to transportation problems. It provides detailed information on dozens of demand management strategies, plus general information on TDM planning and evaluation techniques. The Institute produces it to increase understanding and implementation of TDM (Victoria Transport Policy Institute, 2014).

In transport, as in any network, managing demand can be a cost-effective alternative to increasing capacity. A demand management approach to transport also has the potential to deliver better environmental outcomes, improve public health and build stronger communities and more prosperous cities. TDM techniques link with and support community movements. The term TDM has its origins in the United States of the 1970s and 1980s, and is linked to the economic impact of the sharp increase in oil prices during the 1973 oil crisis and the 1979 energy crisis. When long lines appeared at gas stations, it became self-evident that alternatives to single-occupancy commuter travel needed to be provided to save energy, improve air quality and reduce congestion during peak periods.

However, the Victoria Transport Policy Institute (2014) listed the best TDM strategies for implementation by various organisations and stakeholder groups as shown in Table 4.18:

Table 4.18 Best TDM strategies for implementation by various organisations and stakeholder groups (Source; Victoria Transport Policy Institute, 2014)

Individual actions for efficient transport	Actions that people can take to increase transport system efficiency.
Business actions for efficient transport	Actions that businesses can take to increase transport system efficiency in their roles as employers, developers, building operators and service providers.
Business association actions for efficient transport	Actions that organisations such as Chambers of Commerce and transportation management associations can take to increase transport system efficiency.
Community organisation actions for Efficient	Actions that community and non-profit organisations can take to increase transport system efficiency.

Transport	
Campus actions for efficient transport	Actions that campus managers can take to increase transport system efficiency.
Municipal actions for efficient transport	Actions that municipal governments can take to increase transport system efficiency.
Regional government actions for efficient transport	Actions that regional governments can take to increase transport system efficiency.
State/provincial actions for efficient transport	Actions that state and provincial governments can take to increase transport system efficiency.
Federal actions for efficient transport	Actions that federal governments can take to increase transport system efficiency.
Transportation agency actions for efficient transport	Actions that transportation agencies can take to increase transport system efficiency.
TDM summary table	This table rates all TDM strategies based on their appropriateness for implementation by various organisations and stakeholder groups.

4.5.3.4 Intelligent Transport Systems (ITS)

Intelligent Transport Systems (ITS) combine Information Technology (IT) and telecommunications, allowing the provision of online information in all areas of public and private administration. ITS can be applied to road transport to improve efficiency and safety through by providing drivers in their vehicles with online information and by equipping the vehicle with computerised systems which assist the driver (e.g. flowing and lane keeping). It also uses electronic systems to improve traffic control and traffic regulations enforcement, thus making transport more efficient. In summary, the common uses of ITS can be listed as:

- Emergency vehicle notification system
- Automatic road enforcement
- Variable speed limit
- Collision avoidance systems

- Dynamic traffic light sequence

Electronic motorway tolling and congestion charging are further ITS options. These systems have beneficial effects on the environment by reducing air and noise pollution on highways and by helping to create traffic free zones in cities. (ITS, United Kingdom, 2016).

Although this scenario is tied to Scenario 1 (public transport), this research argues that there are some practical examples across the world, including Los Angeles and Kuala Lumpur, where there are efficient public transport systems but lower ridership because, for whatever reason, they do not have efficient private car reduction policies. In contrast, other cities such as London and Paris used private car reduction strategies in parallel with public transport (see Chapter 7). In other words, a public transport system by itself does not do enough to encourage people left their cars.

4.5.4 Scenario 4: Re-plan land use and urban planning improvement

Another approach for achieving Riyadh's strategic aims is to reconsider how land is used across the city, and how this use affects the type and quantity of trips made between different land use zones. Land use changes are related to many factors, of which transportation is only one. Preston (2010) pointed out the crucial role of transport in urban development in general and city life in particular, indicating areas in which policymakers in developing countries should focus their attention. Gakenhiemer (1999) pointed out that developing countries face similar transport problems, notably shortages in the means of urban transport, and stressed that that, over the years, the responses to these problems, particularly the trend towards market liberalisation, have been inadequate. He concluded that modern transport policies are usually concerned principally with issues such as shortages in the supply of means of transport, the environmental sustainability of transport systems, inadequate transport infrastructures and poor town planning, the affordability of transport fares, a low level of transport

safety and poor reliability. The following section reviews the key issues involved in replanning land use as a solution to Riyadh's traffic problems.

4.5.4.1 Inadequate transport infrastructures and poor town planning

Adequate infrastructure is a key element for continually moving transport. In the absence of infrastructure such as traffic signals, pedestrian walks, wide enough streets and junctions, traffic congestion is likely to impede mobility in cities. Infrastructure development is also linked to both the governance structures of cities and the availability of funds. The need for transport infrastructure imposes patterns of urban land use in many cities. This makes urban planning an essential ingredient in the pursuit of sustainable transport development.

4.5.4.2 Urban sustainability

Another approach hits onto the transport sustainability - complete integration of transport systems. Some authors, like the World Bank (2005), Schipper (2003; 2004), Van Wee (2002) and Diana (2001) point out that current trends in both developed and developing countries demonstrate increased global concerns surrounding sustainable public urban passenger transportation. As a result, they note that urban policy in favour of environmentally friendly public urban transport has increased depending on financial feasibility, country culture, history and geography as well as urban form and land use patterns. Besides, there is a general shortage in urban public transport means.

4.6 Conclusion

This chapter contributes to the research objective of generating and validating future transport scenarios with key Riyadh stakeholders. The specific research questions it answers are as follows:

Research question 7: Where have Riyadh's traffic problems come from?

There are 6 main causes of congestion in Riyadh, from the viewpoint of stakeholders are: 1) Poor planning as Riyadh was adopted by private car as the main method of transport, 2) lack of public transport in terms of poor services which has been covered in research question 3, 3) large-scale projects; under the availability of capital the Saudi government build and develop many mega projects such as King Abdullah financial district KAFD, media city, Riyadh metro, 4) free parking, 5) private car dependency; this were under the factors mentioned in research question no 1, and 6) social trips. The lack of PT system was 26%, which is the highest cause of traffic jams, and has a direct influence on private car usage This is clearly the reason behind the Riyadh metro project.

Research question 8: How are policy transfer issues manifest in current decision making?

Saudi Arabia combines a conservative approach from its religion and culture to society and the state, where the Constitution of Islam is the basic law of all regimes. The decision-makers involved in the development process of transportation projects within Saudi Arabia have full autonomy in dealing with such projects, including the often-bold use of new technology and best-practice approaches from elsewhere in the world.

On the other hand, these approaches are overseen by higher levels of government, specifically The Minister's Council and the Royal Court to ensure that the potentially conflicting aspects of globalisation and Islam are resolved in ways that suit Saudi culture and governance. These policies must be well suited to the cultural and demographic situation of the Saudi context. Saudi Arabia is a country that supports large families and polygamy and maintains the privacy of women who do not want men to share the same seat.

A good example of this is that new trains typically incorporate the latest technology and

high quality engineering, provided by well established (usually Western) providers but they must also contain family sections to maintain the privacy of occupants, and other similar sections dedicated to women travellers; consistent with local cultural norms.

Research question 9: What expectations do key stakeholders have for current and future transport projects?

The interviewees believe that the Riyadh city is rapidly growing and developing. And if public transport policies were introduced in Riyadh, this would be forced to change the travel behavior. They also imagine that Riyadh will be one of the foremost cities in the world within next decade.

They expect many new projects to serve transport system in Riyadh. These projects include: public transport, which includes the Riyadh metro and Riyadh buses, the development of the current plan commensurate with the city's need for sustainable urban transport, establishing new suburbs that will serve about one million people, private cars reduction policies, which includes road pricing and the addition of fees and restrictions on licenses, etc.

They are affirmed that new projects such as Metro and PT will absolutely reduce the congestion. The travel methods it's going to be easy and environment-friendly. Moreover, implementing the strategic plans and projects with continuous studies and researchers to develop our solution such as the capital cities worldwide.

In summary, this chapter reports on a series of semi-structured interviews conducted with key stakeholders in the Riyadh transportation sector, including high-level government decision makers, to help generate future scenarios for Riyadh. The purpose of this was to achieve research objective number three (generate and validate future transport scenarios). Achieving this objective helps the research understand: a) what the policy picture is in Riyadh, b) how policy transfer issues are manifest in current

decision making and c) the expectations that key stakeholders have for current and future projects.

The interviews affirmed many of the insights from the wider Riyadh context (Chapter 2) and policy transfer (Chapter 3), such as congestion sources, current solutions, land use policies and Riyadh's future.

In addition, the chapter provides additional context and insight into other alternative strategies. All of these strategies will be systematically tested in the microsimulation model against the current situation to provide realistic results and look in detail at several network parameters. The next chapter describes how the microsimulation policy transfer test bed for the most congested part of Riyadh was constructed.

CHAPTER 5 Building and Calibrating the Strategic Microsimulation Model of Riyadh City Core (SMM)

5.1 Introduction

This chapter marks an important change of direction for this thesis. While previous chapters dealt with the qualitative aspects of the research, this one marks the beginning of the study of quantitative aspects. Its main purpose is to describe the design and calibration of a traffic microsimulation model representing Riyadh's most congested areas. This model forms the test bed for exploring the policy transfer aspects identified in Chapters 3 and 4, and assessing and visualising Riyadh-specific solutions.

Microsimulation is a new, increasingly popular transport planning method. Its Agent-Based Modelling (ABM) approach involves creating computer models of real road networks and their traffic, and running them many times to detect emergent properties such as queues and congestion. The work described in this chapter forms a substantial part of the analytical effort underlying the thesis. The model itself covers 1.3km by 7.4km in terms of size, and simulates approximately 40,000 trips over a two-hour period between 0630 and 0830. Creating it involved close liaison with the developers of the microsimulation package (SIAS Ltd), while constructing and calibrating it to real-world traffic conditions took more than 12 months. This chapter describes the technical development of the Riyadh microsimulation model, its inputs and the way it was calibrated.

In Saudi Arabia, rapid urbanisation is taking place following the exploitation of oil, which has clearly played a major role in driving the country's economic development, as explained in Chapter 4. According to Glasze & Alkhayyal (2002), this has affected the country in two ways: it has ensured growing individual prosperity for many Saudi citizens, and it has financed the development of transport (most notably the private car) and infrastructure (most notably the development of a road system). It is one of the main reasons why Riyadh has become such a car-dominated city.

Residents of Riyadh use private cars for 93%-95% of their travel needs (Aljoufi, 2012), as described in Chapters 2 and 3. This means that Riyadh's main transportation problem is congestion. The issue has become so critical that several bold land use and transportation solutions are being pursued in a bid to solve the problem (Abdul Salam et

al., 2014). The question this thesis addresses is the extent to which solutions such as the Riyadh Metro (as fully discussed in Chapters 2 and 3) will address these transport problems, and the extent to which policies and solutions used elsewhere in the world could transfer to the Saudi capital's unique circumstances.

Microsimulation is a form of microscopic, scalable, user programmable and computationally efficient traffic simulation that has been used in many applications worldwide (Duncan, 1995). Rather than reducing real-world transport networks down to a smaller subset of 'fundamental' traffic parameters (such as flow, speed, density etc.), it works from the level of individual vehicles. These are endowed with behaviours (such as their origin/destination, speed, following distance etc.), and allowed to interact with each other on a digitally modelled road network that is geometrically referenced to the real thing (Brien et al., 2015). The models are usually run many times, and as the individual vehicles interact, larger-scale collective behaviours (such as queues and congestion) emerge. Microsimulation captures and observes the behavioural aspects of transport networks, and, as such, has proven invaluable in studies of Intelligent Transportation System (ITS) facilities and strategies, changing patterns of land use, junction design, signal timing and much more. Unfortunately, this exciting tool is currently lacking in Riyadh.

This chapter briefly evaluates microsimulation as an approach to transport planning, the development of a microsimulation model of a transport corridor in Riyadh, its calibration to live traffic situations, and how it can be used to reveal the structure and character of Riyadh's existing transport challenges. It then moves on to consider the role of such models in exploring and visualising larger-scale policy interventions, and communicating them effectively to stakeholders.

5.2 Microsimulation: A novel approach

Microsimulation is an effective tool used for reproducing and analyzing a broad variety of complex problems such as traffic congestion, which is difficult to study by other means that might be too expensive or dangerous, therefore simulation is a suitable tool

to analyze traffic systems (Bazghandi, 2012). Traffic micro simulation is the state-of-the-art method used to assess and evaluate transport schemes for reducing congestion. Rather than implementing a scheme without knowing whether the outcome will be a success, the scheme can be implemented in a simulation to determine its effectiveness (Bazghandi, 2012).

A model is a representation that should explain all relevant facts. Models are used in transportation to simplify complexity, and to understand how transport networks (and the people using them) work and plan for the future. In such models, all vehicle groups tend to obey the same (usually economic) behavioural rules, and the models themselves are mathematically predisposed to achieve equilibrium states. The limitations of this approach have started to become apparent. In the 1950s and 60s, models like these were part of a ‘predict and provide’ approach to transport planning. Transport infrastructure would be provided based on predicted future demand, from which specific capacities, flows, speeds etc. could be defined.

A range of phenomena from ‘induced demand’ through to queueing behaviours introduced a range of inaccuracies in these models and gave rise to unsatisfactory outputs. This, combined with advances in computing power, drove an interest in alternative approaches, of which traffic microsimulation is one. In many cases, ABM is most natural for describing and simulating a system composed of “behavioral” entities. ABM makes the model seem closer to reality. For example, it is more natural to describe how vehicles move in a lane than to come up with the equations that govern the dynamics of the density of vehicles (Bazghandi, 2012).

Traffic microsimulation is a more recent approach that breaks away from this mould. Rather than a deterministic model in which macro-level traffic parameters can be extracted, microsimulation models are agent-based and use the combined/emergent behaviour of individual vehicles, each with its own probabilistic behaviour profile, interacting on a modelled road network as shown in Figure 5.1. Rather than

deterministic outputs expressed as integers, microsimulation gives rise to probabilistic outcomes that can be visualised directly. It's an increasingly popular approach. Computer models in which the movements of individual vehicles travelling around road networks are determined through simple car following, lane changing and gap acceptance rules are increasingly used to evaluate and develop road traffic management and control systems.

This technology includes traffic demand management systems, ITS, traffic modelling and design systems. In some countries (for example the UK, North America, Australia and New Zealand), it's common for local government to develop a plan covering the future development of the towns and cities in its area for the next five or 10 years. These plans often cover land use issues as well as the development of the transport system.

For larger settlements, it's usual to develop a transport model so as to make the best use of the money needed to improve the transport system. The authority will keep the transport model and use it as the need arises to change the transport plan, investigate new transport opportunities and understand the impact of the development of new sites.



Figure 5.1 3D animated outputs from the microsimulation tool (Paramics, 2014)

This thesis uses microsimulation because it's highly consistent with both the underlying theoretical perspective of the research (i.e. systems thinking), but also very new for Riyadh. In other words, it helps realise the aim of making both a theoretical and practical contribution to the existing knowledge. Microsimulation will help to simulate Riyadh's traffic conditions and visualise and explore the complex issues involved in a new way. The following sections explain how the study area was selected.

5.3 Defining the study area

The city of Riyadh covers an area of 600 square miles and has a population of eight million. It was therefore well beyond the resources of this research to design, develop and calibrate a city-wide microsimulation model on this scale. An endeavour of this scope had never been undertaken previously, and would take a large team several years of work. However, it is possible to focus on Riyadh's most congested area and construct what is known as a strategic model. This does not cover the whole city, but it does enable city-wide inputs and influences to be captured. Defining the study area is the first step.

The Arriyadh Development Authority (ADA) has carried out various studies into the city's development needs through the ongoing (MEDSTAR) project. From these and other studies, there is strong evidence that demand exceeds road space capacity, and there is extensive and sometimes prolonged traffic congestion every weekday on parts of the Makkah Expressway and the King Fahad Freeway, as well as on arterial roads in central Riyadh (Figure 5.2).



Figure 5.2 Traffic congestion in typical peak-hour conditions on the King Fahd Freeway (ADA, 2015)

Research undertaken by Wood (2012) identified key bottlenecks in 30 locations across the city, with priority order based on an un-weighted combination of:

- Level of congestion
- Actual and predicted traffic volumes
- Actual delays and problem-solving capabilities

Twenty seven of these bottlenecks were chosen for further analysis based on priority criteria as follows (Figure 5.3)

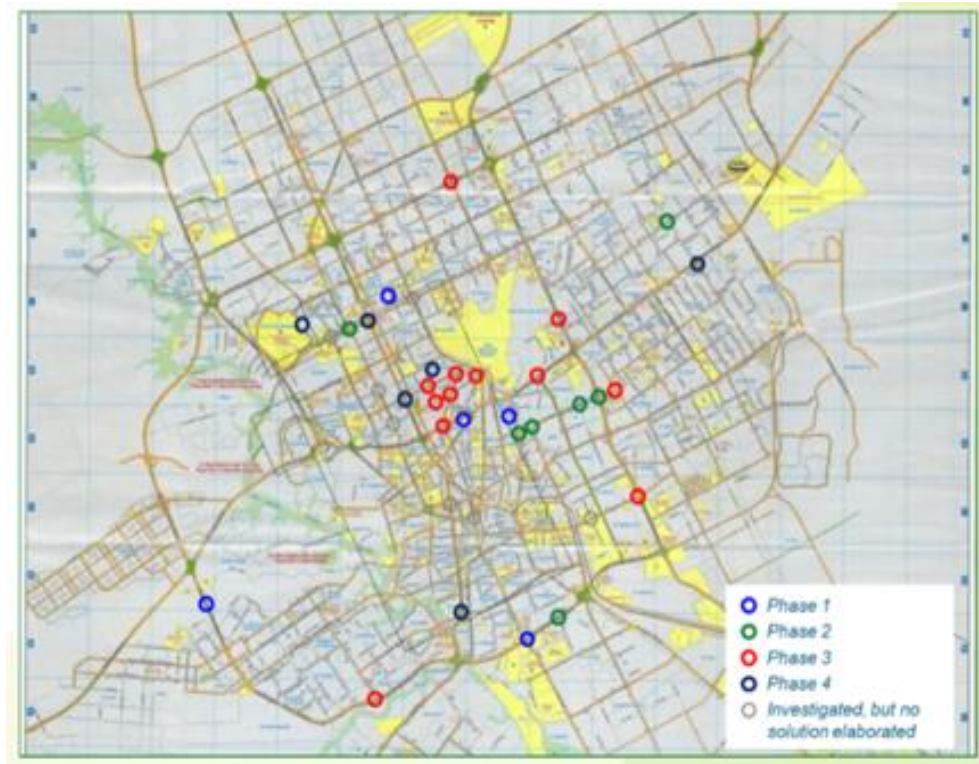


Figure 5.3 Bottlenecks identified in the road network of Riyadh (ADA, 2011)

The priority traffic bottlenecks are spread over a large area. As noted above, it is not possible, given the time and resource constraints of this research, to construct a microsimulation model of the whole city. However, it is clear that many of these priority bottlenecks cluster in an area of Olaya and in the north of the city centre. This area will form the focus of this study (Figure 5.4). It has a unique character compared with other parts of Riyadh due to the following characteristics:

- It was planned as Riyadh's commercial and businesses zone
- The building regulations in the area allow for unlimited building height
- Land use in the area is mixed
- It includes the main shopping centres and luxury hotels (Riyadh Municipality, 2014)

All these factors combine to give very high trip generation and attraction potential.



Figure 5.4 The main commercial road in Riyadh (yellow) (ADA, 2011)

The study area encompasses four main axes which dissect the city horizontally and vertically, and it lies on a principle axis for vehicular traffic. Figure 5.5 shows a skeletal outline of the study area, indicating the principal routes and junctions. This outline view is perhaps visually misleading because it is, in reality, very large. The study area is 7.4km long from south to north and lies adjacent to Olaya, the district beside Olaya Street and King Fahd Road. In the other direction, it is 1.3km wide. This is a total land area of approximately 10sq km.

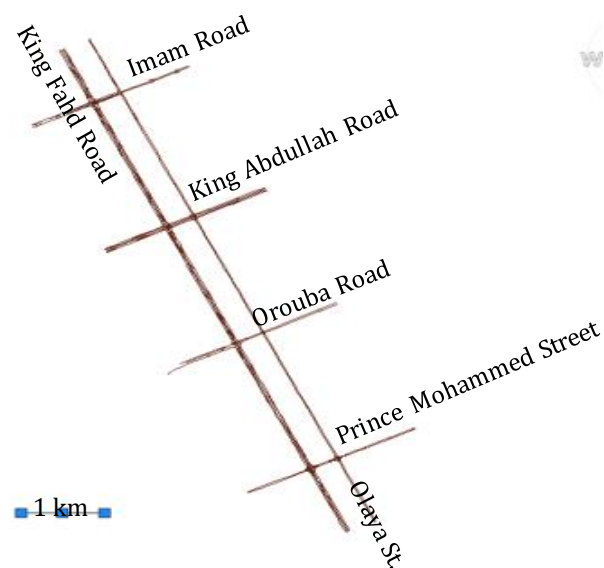


Figure 5.5 The key roads in the study area (Original; Author)

Despite the large size of the study area, detailed information on its topography and layout exists in DXF format. This displays high-resolution mapping and the Riyadh Municipality produced it and provided it to the author in support of this research. The DXF map, which is approximately 28GB in size, was cut to the required area and inserted into the microsimulation software, which in this case was Paramics Discovery. This is one of the leading microsimulation packages currently available, and it was developed by Edinburgh-based SIAS Ltd. The author worked closely with this company, often at their offices, to develop the model which, at the time of writing, was the largest to be developed using this particular software version (Paramics Discovery).

5.4 Developing the Riyadh Microsimulation Model

The major steps involved in a microsimulation analysis are shown in Table 5.1.

Table 5.1 The major steps involved in microsimulation (in order) (Original: Author)

Step order	Action	Description
1	Identification	Identification of project purpose, scope and approach. This scoping step is critical for determining the ultimate cost and schedule of the microsimulation analysis. (Which has been covered above.)
2	Data collection	Involves collecting input data for the microsimulation model, as well selected output data for calibrating the model
3	Coding	Coding is the conversion of field data into inputs for the microsimulation model
4	Error checking	This verifies the accuracy of the coded input data
5	Model creation	This involves all tasks needed to build up the model including roads overlay, nodes, traffic matrix and visual appearance
6	Calibration	The adjustment of the default parameters in the standard behavioural models contained in the microsimulation software so that it accurately models specific local conditions
7	Alternatives testing	This is the purpose for which the microsimulation model was developed, and will be covered in subsequent chapters
8	Documentation	This provides information on the inputs to the model, the validity of the model and the results of the alternatives

		analysis (see Sections 6.1 and 6.2)
9	Presentation	Presentation of the results. This is the step in which the analyst presents the microsimulation analysis results to decision makers and the general public.

The following sections explain the activities performed at each stage to develop the corridor model of Riyadh.

5.4.1 Step 1: Identification

This step is covered in previous chapters and in the section outlining the study area above.

5.4.2 Step 2: Data collection

The microsimulation model requires the following input data, all of which was sourced directly from the Riyadh Municipality, the ADA and the Ministry of Transport. Some of this data was, in turn, collected on behalf of ADA by the Saudi Consolidated Engineering Company (SCEC), the consultants for the MEDSTAR project. Launched in 2013, this includes key development strategies such as the Riyadh Metro, currently the world's largest subway project in terms of its length (176km) and budget (USD 22.5 billion).

In addition, many consultants working on this project (e.g. Siemens, Alstom and Bombardier Transportation) have carried out professional transportation studies for specific purposes, and this data has also been sourced and used where appropriate. Table 5.2 summarises the data inputs needed for the corridor model, the data used and its source. These are expanded further in the following sections.

Table 5.2 Sources of data used to create the Riyadh corridor model, a brief description, its format and its source (Original: Author)

Data required	Description	Format	Source
Geometry (lengths, lanes, curvature)	Riyadh map, study area satellite photograph	DXF	Riyadh Municipality
	Road plans, kerbs, junctions	DWG	ADA

Controls (signal timing, signs)	Signal timings from all 20 junction installations	XLS	ADA
Existing and future demands (turn volumes, OD table)	All origin-destination (OD): The OD table was provided as multi-destination tables of each junction with specific time and junction criteria. This data was collected to create a comprehensive study for the Riyadh Public Transport Project in 2010.	XLS	ADA
Calibration data (performance data: speeds, queues, etc)	This data was taken from the annual performance record project provided by the Department of Road Services Quality	DOC, XLS	Ministry of Transport

5.4.3 Steps 3 and 4: Coding and error checking

Coding is the process of converting the raw data shown in Table 5.1 into a functioning microsimulation model. The analysis software requires that the information from the raw data be inputted in a specific way. For example, for road properties or categories, the software needs all physical measurements in metres: it also needs to know the road kerbs and junction types, which are already saved as part of a basic template, and when to create new types within road categories. It is important to code the raw data in such a way that the resulting model is consistent with the real network. Table 3 shows the coding and error checking of raw data.

Table 5.3 Coding and error checking of raw data (Original: Author)

Item	Description
Units	Changing units as required (metres, seconds etc.)
Road category	Highway, arterial, urban etc.
Road specification	From American (Saudi standard) to British standard (model-based)
Kerbs	Rescale the kerbs of the junction or between two ways
Left-hand drive	Changing the model to left-hand drive

5.4.4 Step 5: Creating the road network

The first step in creating the corridor model is to import a geographically and topologically correct map into the microsimulation package. As noted above, the map was obtained from the Riyadh Municipality and took the form of a high-resolution DXF file. This was 28 GB in size, covering around 10 sq km.

Creating the microsimulation model involves, in essence, overlaying a network of links and nodes across the top of the DXF file. The links correspond to roads, and the nodes to junctions. Once this step is complete, and a basic network created, the properties of each link and node are changed so that they reflect the ‘actual’ road or junction type.

Microsimulation provides templates for all types of junctions, so it is possible to modify the template as needed with any scale. Moreover, every component can be modified to fit real-life shapes, such as traffic signs, roundabouts, tunnels or multi-level roads. Furthermore, a wide variety of road categories enable all specifications for each road component to be specified in detail, including: road type (highway, urban or walking street), speed limit, lanes, kerbs, etc. Figure 5.6 shows a screenshot of the basic network and the means by which nodes and links are modified (via menus of properties).

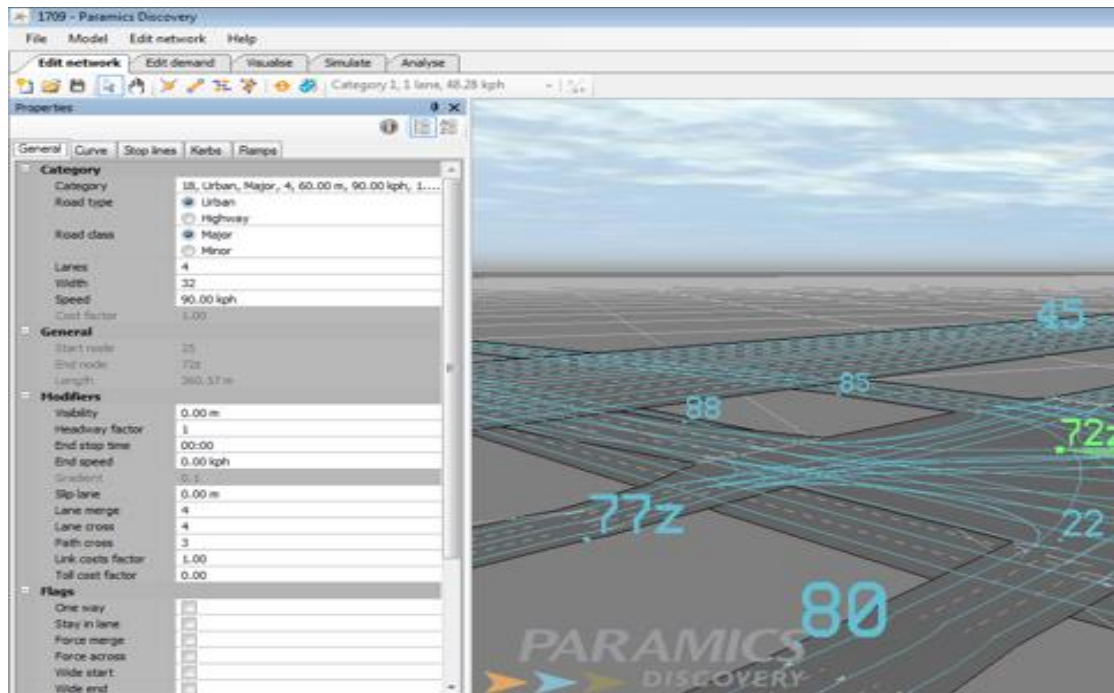


Figure 5.6 A screenshot of the basic network comprising links and nodes corresponding to the underlying DXF file of the 'actual' roads and junctions in the study area. Each link and node is modified by means of menus containing properties, so that it represents the specifics of the real road network. (Original: Author)

5.4.4.1 Creating the Traffic Matrix (Origin/Destination matrix O/D)

After specifying and defining the road layout and topology, the next step is to populate the model with vehicles. Doing this requires information on the total volume of cars at specific times and on specific routes, which is called the Traffic Matrix (TM). This comprises traffic *origins* on the Y axis and traffic *destinations* on the X axis. (e.g. If a vehicle comes from King Fahd Road southbound travelling northbound, i.e. from Zone 8 to Zone 16, it would add to the total in that cell). TMs reflect the volume of traffic flowing between all possible pairs of sources and destinations in a network.

The knowledge a TM represents lies at the heart of traffic analysis methods and so it is used for a wide variety of traffic engineering tasks, including load balancing, routing protocol configuration, dimensioning, provisioning and failure strategies. Information on the size and locality of flows is crucial for planning network growth and diagnosing problems (Medinaa et al., 2002), and is a critical part of the current study.

Future scenarios will, in part, be created by manipulating this underlying TM (shown in Table 5.4). The total number of vehicles in the study area was defined during a two-

hour period between 0630 and 0830, and amounted to 39,815 vehicles. This time period was chosen because it reflected peak traffic conditions for the study area and the conditions which future transport projects and interventions need to mitigate.

Table 5.4 Traffic matrix showing the volume of vehicles flowing between each origin/destination pair across the study area (Original: Author)

Codes (street names)	Olaya Street North	King Fahd North	Mohammed West	Orouba West	Orouba West	King Abdullah West	King Abdullah East	Immam West	Olaya South	King Fahd South	Immam East	Mohammed East	
Zone no.	7	8	9	10	11	12	13	14	15	16	17	18	
From zone (zone no.)	OL N	KFR N	MOH W	OR W	OR E	KAR W	KAR E	IM W	OL S	KFR S	IM E	MOH E	TOT.
OL N (7)	0	556	244	422	286	52	7	33	33	16	14	7	1670
KFR N (8)	186	0	349	192	75	54	94	5	5	5000	4	447	6411
MOH W (9)	289	239	0	240	216	67	73	11	7	1	5	693	1841
OR W (10)	52	230	172	0	525	288	362	76	48	11	5	50	1819
OR E (11)	298	66	40	435	0	234	411	148	148	36	66	52	1934
KAR W (12)	435	65	140	280	369	0	1200	1121	554	472	1418	229	5474
KAR E (13)	257	60	30	54	85	1200	0	169	169	51	155	64	1324
IM W (14)	169	86	63	276	16	1245	147	0	318	176	2000	48	4544
OL S (15)	137	53	32	122	45	667	122	435	0	80	161	34	1888
KFR S (16)	27	4000	9	56	75	300	62	624	230	0	239	42	5664
IM E (17)	105	21	15	98	115	474	87	3000	100	680	0	107	4802
MOH E (18)	698	752	334	331	144	91	46	16	16	12	4	0	2444
TOTAL	2653	6128	1428	2506	1951	3702	1802	5638	1628	6535	4071	1773	39815

The model is, of course, surrounded by other areas of the city. These serve as source or sink nodes for traffic entering or leaving the study area. Information on these surrounding areas also needs to be represented in the model. The key areas surrounding the corridor model are shown in Figure 5.7 below:

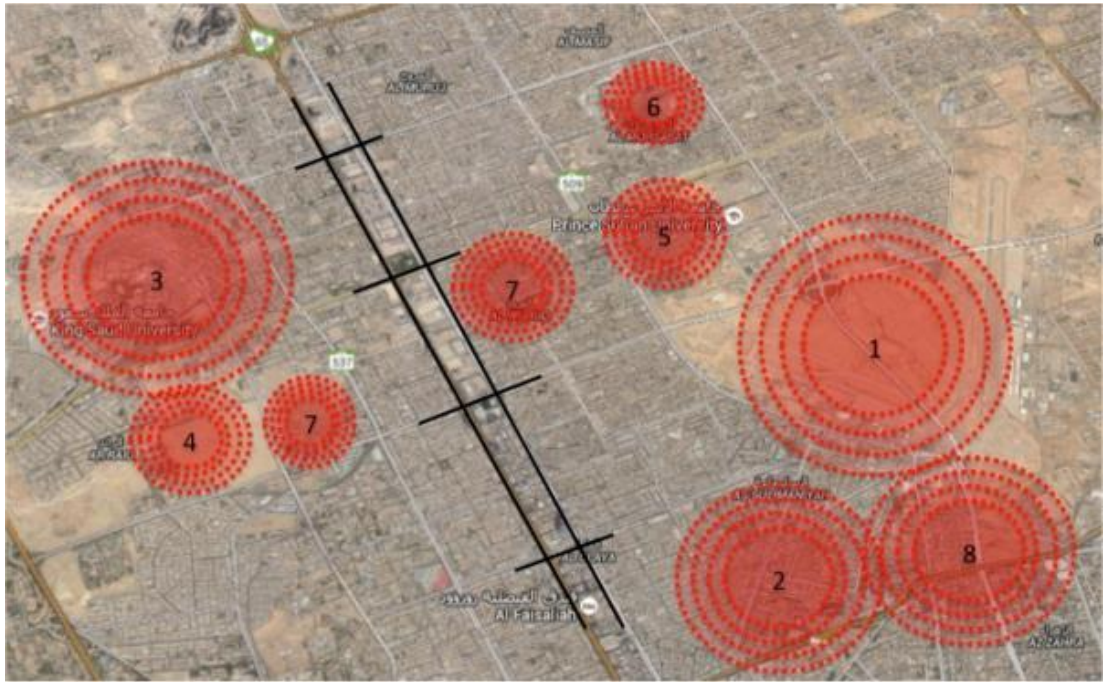


Figure 5.7 Main activities surrounding the study area were: 1. Riyadh Air Base, 2. King Fahad Medical City, 3. King Saud University, 4. King Abdulaziz City for Science and Technology, 5. Prince Sultan University, 6. Saudi Telecom Company, 7. Alhabib Hospital, 8. Prince Sultan Military Medical City (Original: Author)

The size of the circles indicates the degree of traffic activity in the area. In some areas, there is a greater possibility of cars diverting to nearby routes than others. For example, if we assume that there are 500 trips coming from the Riyadh Air Base, a large proportion will take King Abdullah Road instead of Orouba Road or Prince Mohammed. These wide area inputs need to be considered in the calibration phase to be discussed shortly.

After adding all traffic volumes into the O/D, the next step is to set the matrix profile. In other words, the total volume of vehicles between each origin/destination pair does not enter the network all at the same time. For example, 1,106 vehicles were travelling from Zone 10 at 0645 to KFR S (Zone 16) (see table 5.4), and this number decreased to 845 at 0710 (measured every five minutes). This is because during school and peak working

hours, car congestion increases across the network. These variations in the ‘release rate’ of flows between origins/destinations are adjusted for each cell in the O/D as shown in Figure 5.8.

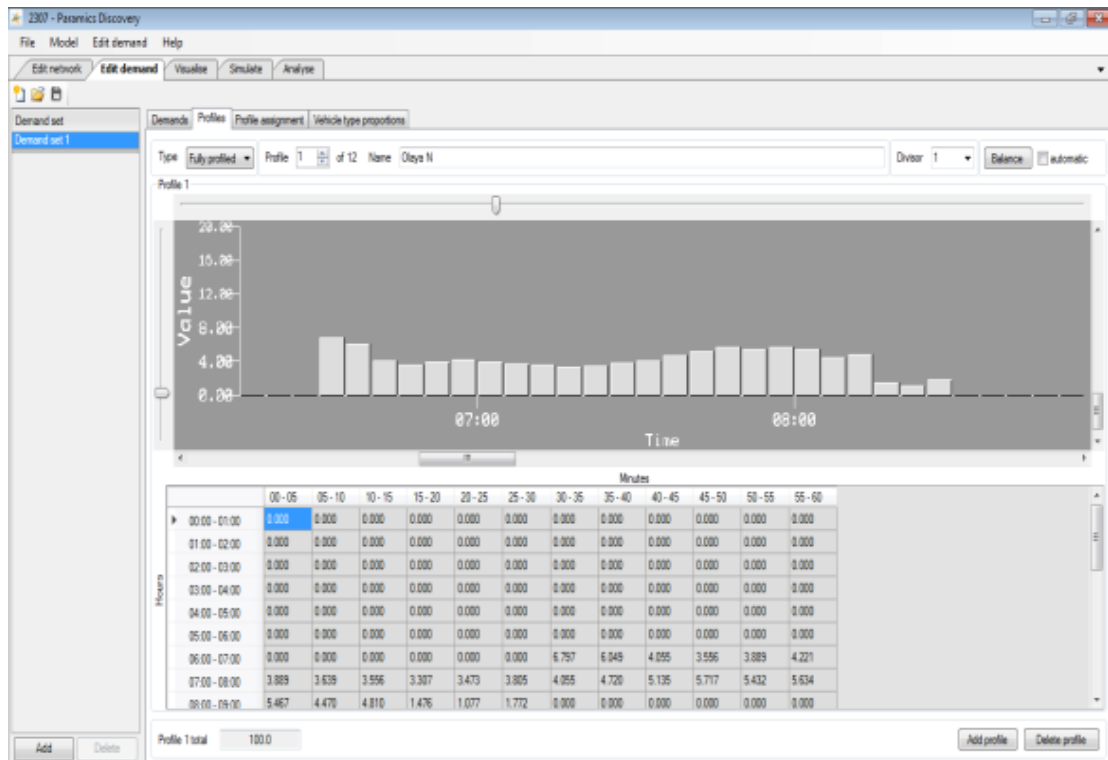


Figure 5.8 Example of a profile assignment for King Fahad Road (KFR), showing how the volume of traffic varied over the two-hour peak period (Original: Author)

5.4.4.2 Visual Appearance and Vehicle Behaviours

As seen in Figures 5.9 and 5.10, one of the key strengths of traffic microsimulation software, including Paramics, is that it simulates the individual components of traffic flow and congestion, and presents its output as a real-time visual display for traffic management and road network design. This is an extremely compelling way of visualising the network and any changes that are made to it, and is a key factor in microsimulation's success.

For presentation purposes, a fairly basic visual appearance was chosen. This is consistent with the research's aims. While it is possible to add photorealistic scenery and buildings, the focus of this model was the road network itself and how the traffic behaved. The images below provide some snapshots of the Riyadh corridor model's visual appearance.

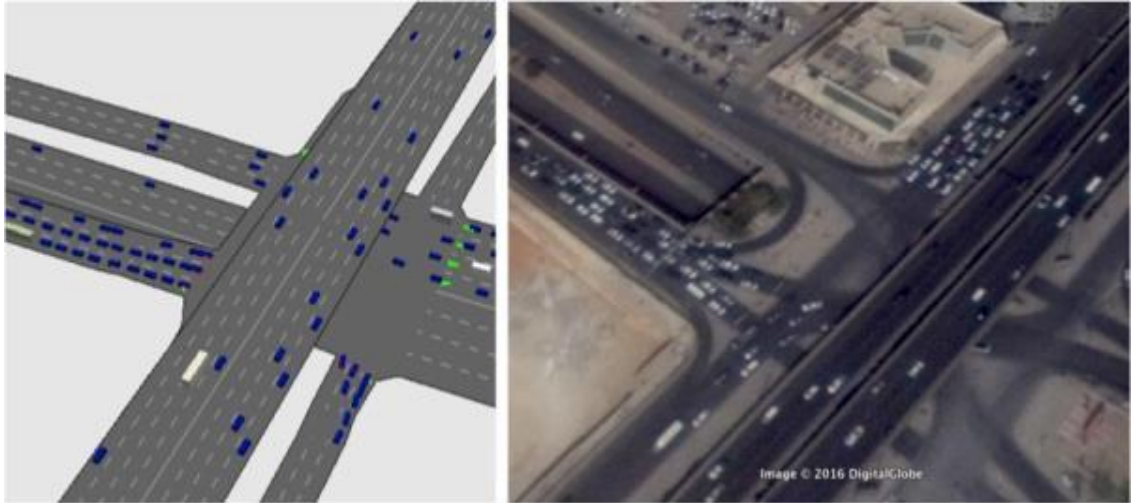


Figure 5.9 Visual display for three level junctions on KFR via KAR, snapshot of model (left) Google imagery (right) (Original: Author)

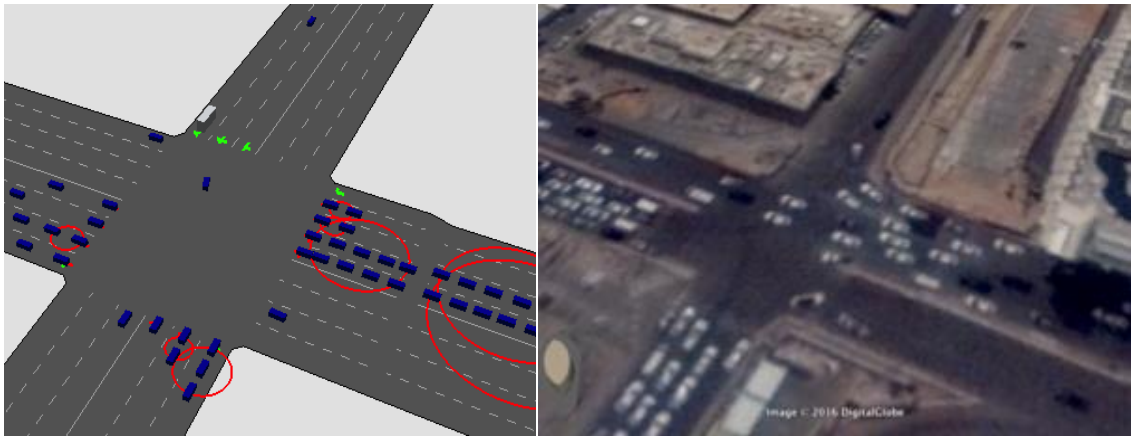


Figure 5.10 Visual display for one level junction, OL via MOH, snapshot of model (left) Google imagery (right) (Original: Author)

Virtual vehicles enter the network as specified by the underlying origin/destination and demand matrices (see Table 5.4 above). As these vehicles enter the network, they interact with others according to behavioural rules. They will follow at certain distances, travel at certain speeds, have different levels of ‘aggression’ and so forth.

Table 5.5 below provides an overview of the behaviours individual vehicles were endowed with on the network, and what these individual settings mean:

Table 5.5 Summary of vehicular behaviour settings (Original: Author)

Setting	Definition
Vehicle ID	Each vehicle has taken ID serial number
Speed	Fixed speed limit on usual traffic conditions (influencing factors include speed limit, vehicle following, link curvature, gradient and aggression)
Lane	Current lane
Lane range	Possible lanes to use
Next lane	Desired lane on next link
Origin	Origin zone
Destination	Destination zone

The product of these interactions is the complex behaviour seen in real life, from queues and shockwaves to drivers finding alternative routes and becoming stuck in jams. One of the products of these individual interactions in the Riyadh corridor model is pronounced queues, which can be visualised in a number of ways. Figure 5.11, for example, shows larger circles depicting where more cars are queuing.

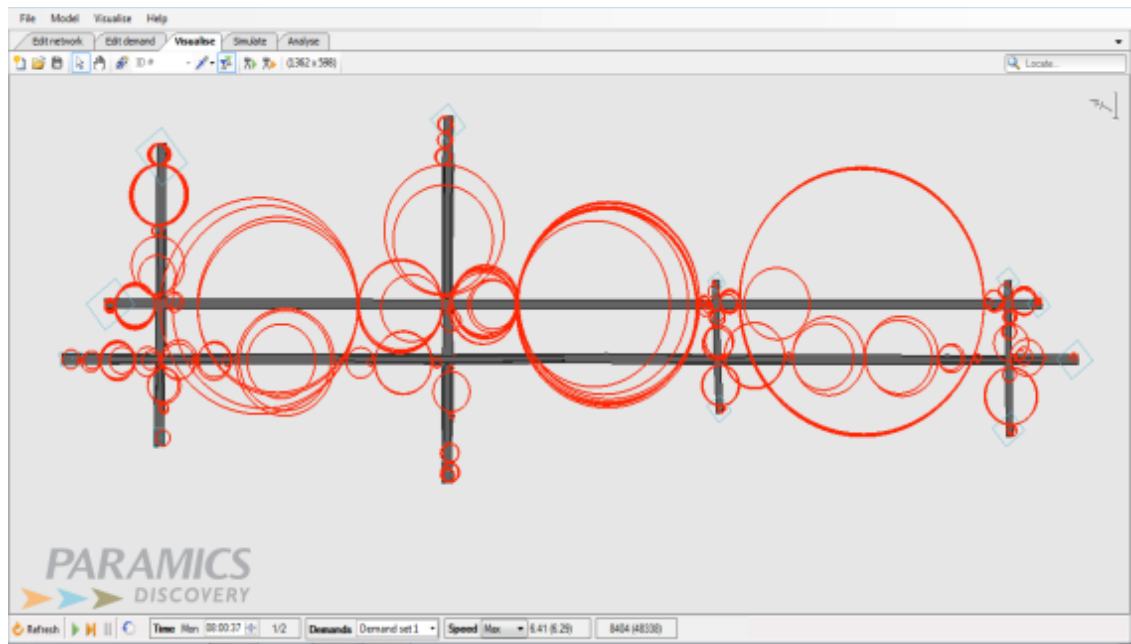


Figure 5.11 Traffic queues and bottlenecks can be visualised in several ways, including with circles representing queue length (Original: Author)

Figure 5.12 shows Olaya Street from Junctions A to C for each southbound and northbound direction at 0805.

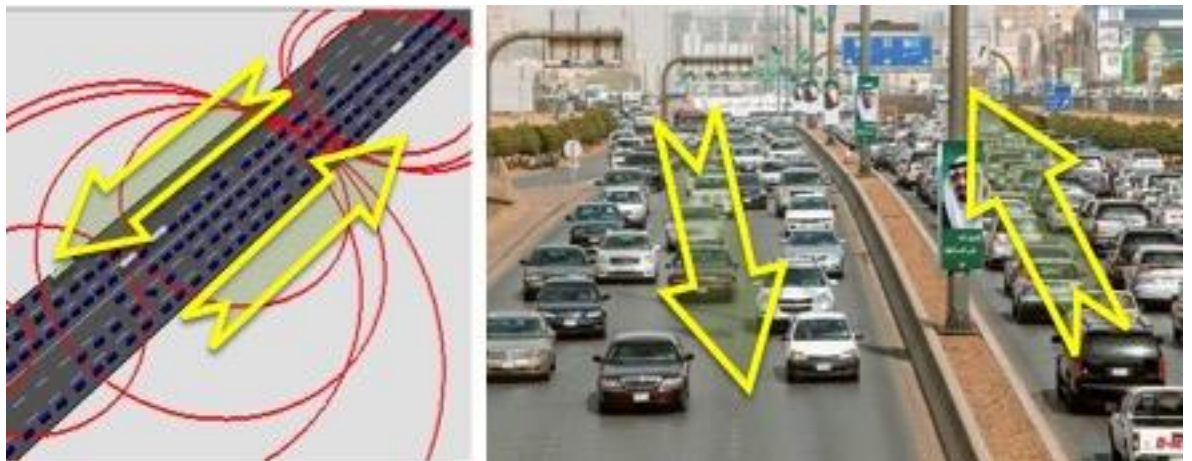


Figure 5.12 Visual representation of a queue derived from the microsimulation model and what it represent in the real traffic network (Original: Author)

As previously mentioned, this model was created and calibrated to serve the purpose of this research, to be as test bed for the future scenarios of the city of Riyadh on strategic level. Although Paramics allows modifying and adding the parameters of driving conditions for any country, for example; these parameters can make changes on the

vehicles speed in a given range/zone, the stopping approach at intersections, driving style, speed and lane changing behaviour, but the search has adopted the basic settings of the parameters taking into account the road and vehicle settings that were set as mentioned in section (5.4.5.1.1) In general, such parameters are more widely used for pure transport engineering or on a smaller scale than strategic models

5.4.5 Step 4: Calibration

Models are used to explain and predict the behaviour of real objects or systems, and are used in a variety of scientific disciplines. (Kara Rogers, 2016). Testing the extent to which a model performs this function is referred to as calibration, and this is an important step in traffic microsimulation. Model calibration refers to the process of assuring that a model reproduces real-world traffic conditions reasonably well. Figure 5.13 shows the activities and structure forming the calibration process:

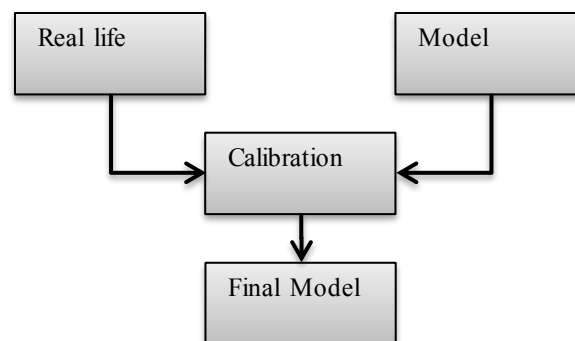


Figure 5.13 Calibration process (Original: Author)

Microsimulation models which have not been properly calibrated can produce unrealistic or misleading results. Therefore, before applying the model, it must be properly calibrated (WisDOT, 2014). This section addresses the steps, computations and criteria for determining whether the simulation model is reasonably consistent with local reality.

5.4.5.1 Calibration issues

The starting assumption is that the model and software developers have already validated and verified the behavioural models and application software. This leaves the task of adapting the behavioural models to local conditions. Thus, the first step is to check and eliminate coding errors.

5.4.5.1.1 Check for and eliminate all obvious coding errors

The model was run and visualised and, based on this visualisation, various issues were detected and corrected. Calibration was performed across the whole model. The main calibration issues detected (and subsequently corrected) are shown in Table 5.6.

Table 5.6 Calibration activities performed on the Riyadh corridor model (Original: Author)

Location	Issue	Calibration
Traffic light timing at all junctions	Traffic police adjust the traffic light manually in peak time	Extended times to the congested routes by observation
Lanes at all junctions	Lane 1 goes left Lane 2 goes ahead & left Lane 3 goes ahead & right Lane 4 goes right	Added Lane 3 to turn left or right depending on the congestion situation
All junctions	Right turn possible when red sign	Gave priority to Lane 4 at any time
Unreleased vehicle	Vehicle unreleased due to the distance between release zone and junctions	Extended the distance
Junction E eastbound	Vehicle stock on turn right lane	Joined Lanes 3 and 2

5.4.5.1.2 GEH statistic

There are various ways of comparing modelled and actual traffic volumes. The favoured approach in this analysis is the Geoffrey E. Havers (GEH) statistic (WisDOT, 2014). This is widely used within the UK's Design Manual for Roads and Bridges, and is effective in resolving a number of important calibration issues. In particular, traffic volumes in different portions of a highway corridor typically vary over a wide range. The mainline of a freeway might carry 5000 vehicles per hour, while one of the freeway's on-ramps may carry only 50 vehicles per hour. In that situation, it would not be possible to select a single percentage that could be used as a model acceptance criterion for both volumes.

In other words, setting a volume tolerance of 5% would permit a modelled mainline flow of 5000 ± 250 vehicles, which would be very lenient compared with the ramp tolerance of 50 ± 3 vehicles. Some traffic modellers use a matrix of tolerance percentages for various volume ranges, but this can be cumbersome and is prone to mathematical discontinuities. To overcome these problems, Geoffrey E. Havers developed a continuous volume tolerance formula. Colleagues dubbed it the GEH formula.

Although its mathematical form is similar to a chi-squared test, it's not a true statistical test. Rather, it's an empirical formula that has proven useful for a variety of traffic analysis purposes (WisDOT, 2014). The GEH formula is designed specifically for the comparison of hourly modelled and observed flows. Both relative and absolute differences are taken into account when calculating the GEH value as follows:

Equation 2 GEH calibration

$$G_H = \sqrt{\frac{2(m - c)^2}{m + c}}$$

Table 5.7 Modelled and calibrated value for overall traffic volume (Original: Author)

Code	Description	Value
M	Traffic volume from the traffic model	39815
C	Real-world traffic count from raw data collected	42705
GH	In an Excel spreadsheet, if the modelled is in cell M1 and calibrated is in cell C1, this would be written as: =SQRT((0.2*M1^2-0.4*C1*M1+0.2*C1^2)/(M1+C1)) (WisDOT, 2014)	4.499%

The GH formula was applied to the SMM as follows. A two-stage process was used, in which the first stage involved applying the GEH formula to total flows across all the modelled junctions.

On checking the outputs, if any of the junctions posted a GEH value in excess of 5%, the second stage would follow. This stage involved applying the GEH formula to each branch and each individual modelled flow in the junction in a separate analysis. This reveals specific areas of poor calibration which need to be corrected. Table 5.8 presents the outputs of Stage 1 calibration:

Table 5.8 GEH calibration for each junction (Original: Author)

Location	M	C	GH
Junction A OL via MOH	1197	1368	1.05%
Junction B KFR via MOH	9170	8378	2.67%
Junction C OR via OL	1130	934	1.92%
Junction D OR via KFR	9687	11104	4.3%
Junction E KAR via OL	2570	3117	3.2%
Junction F KAR via KFR	11400	9701	5.2%
Junction G IM via OL	5170	6109	3.9%
Junction H IM via KFR (estimated)	13000	13000	0

The UK Design Manual for Roads and Bridges (DMRB) suggests that a GEH value of below 5% represents a satisfactory match between modelled and observed traffic flows. The mean GEH value achieved across the whole model after all necessary calibration

steps were complete was 4.499%.

According to the DMRB (2014), this represents a satisfactory model fit, and a basis for using the corridor model in testing future scenarios. None of the individual junctions had a reading greater than 5%, and so there was no need to invoke the second stage. Bearing in mind, the model's purpose (as a strategic model), these results are more than satisfactory.

5.4.6 Formal model audit

SIAS, the software developer, performed a formal model audit of the sort routinely applied to commercial models (No. Model ID – 2809). Table 5.9 summarises the main audit results with brief descriptions of the model issue and performance. The full model audit is found in the Appendix.

Table 5.9 SMM audit report from SIAS (Original: Author)

Aspect	Elements	Description
Initial model review	Errors and warnings	There were no errors or warnings when loading the model
	Network-wide behaviour parameters	All of the network-wide behaviour parameters are set to default as expected
Assignment and zones	Generalised cost equation coefficients	The generalised cost equation gives complete weighting to distance and does not include any coefficient for time
	Major and minor links Categories	Major links have been used throughout, which is appropriate
	Familiarity	The familiarity has not been changed from default for any vehicle types
	Category and link cost factors	No category or link cost factors have been used, which, again, seems appropriate
	Perturbation	Perturbation has not been changed from default for any vehicle types
	Dynamic feedback	Dynamic feedback has not been enabled,

	assignment	which means there will be no re-routing in response to congestion on the network
	Zones	Zone placement is good
Demands and profiles	Demand release profiles	Profile development and assignment look good
	Matrix levels/Demand sets	One matrix level and one demand set has been used. Since the model covers one time period and is over 97% cars. this is appropriate.
Public transport and vehicle types	Public transport	There is no public transport in the model
	Vehicle types	The range of vehicle types used seems sensible
Network coding	Node and link structure Kerbs and stoplines	The model hasn't been checked against the overlay, but on the whole the node and link structure looks good and the kerb positions seem sensible
	Link properties	Urban links have been used throughout the network except on King Fahd Road, where highway links have been used
	Signal junctions/crossings	The signal-controlled junctions in the model are coded reasonably well.

5.4.7 Running the base model

Having completed the first four steps of the model development process, the end result is known as a 'base model'. This is a calibrated model representing the study area well enough to allow further analyses to take place.

In this section, the base model is run and a number of key indicators extracted. These (and others) will be used as points of comparison when the model is changed to reflect alternative transport strategies in Riyadh.

5.4.8 Network observation

Network observation is an important feature of microsimulation, and one of its key benefits. It's a way of communicating complex system ideas and results to stakeholders.

They can actually ‘see’ the emergent phenomena and complexity with their own eyes. In this step, the calibrated corridor model was run and its performance observed visually. The results and key features are shown in Table 5.10 as follows:

Table 5.10 Key features observed (Original: Author)

Key feature	Location	Time
Worst congested minute	All	0710
Substantial queuing (time)	KFR to KAR and IM (in and out)	0715
Substantial queuing (length)	KFR Northbound	0730
High volume	KFR, KAR and IM	All
Most congested junctions	IM eastbound via KFR KAR westbound via KFR	0705
Most congested lanes	1,2 KAR+ 1,2MOH+ 1,2,3, and 4 IM goes to KFR	0710

However, the reasons behind these results will be justified in the following sections.

5.5 Indicators

When the model is run, a separate data analysis tool begins to investigate and analyse it and provide critical and final indicators for assessing network performance. The software extracts a wide range of environmental and economic factors, but for now a number of more traffic-focused indicators are derived. These are as follows:

- Levels of Service (LoS)
- Traffic flow
- Journey time
- Queue length

5.5.1 Indicator 1: Level of Service (LoS)

Level of Service (LoS) of a traffic facility is a concept introduced to relate the quality of traffic service to a given flow rate. LoS is introduced by Highway Capacity Manual (HCM) under different operational characteristics and traffic volumes. HCM expresses LoS as a letter that designates a range of operating conditions on a particular type of facility. HCM defines six LoS letters, namely A, B, C, D, E, and F, where A denotes the best quality of service and F the worst. (Mathew, 2014). Table 5.11 shows the LoS for a basic freeway segment:

Table 5.11 LoS for a basic freeway segment (Original: Author)

LoS	K (veh/km/lane)	FFS (km/hr)	v/c
A	0-7	120	0.35
B	7-11	120	0.55
C	11-16	114	0.77
D	16-22	99	0.92
E	22-28	85	1.0
F	> 28	< 85	> 1.0

SMM outputs shows the LoS for the only highway within the study area (King Fahd Road (KFR)), as shown in Table 5.12:

Table 5.12 LoS for King Fahd Road (Original: Author)

	K (veh/km/lane)	FFS (Km/hr)	v/c
KFR	53	40	1.52

In addition, signalised intersection LoS is defined in terms of a weighted average control delay for the entire intersection. Table 5.13 summarises the LoS criteria for signalised intersections, as described in the Highway Capacity Manual 2010 (Transportation Research Board, 2010).

Table 5.13 LoS for an intersection (Original: Author)

LOS	Control delay sec/veh(signalised)	Delay sec/veh (unsignalised)
A	≤ 10 10-20	≤ 10 10-15
B		
C	20-35	15-25
D	35-55	25-35
E	55-80	35-50
F	> 80	> 50

SMM found that all weighted average control delays for the intersections take more than 80 sec/veh which is F grade.

The following figure shows the average delay time (in seconds) for each junction via all directions, as shown in Figure 5.14.

**Figure 5.14 Average delay time (seconds) for each junction via all directions (Original: Author)**

5.5.2 Indicator 2: Traffic flow

As mentioned in the case study chapter, Riyadh has grown rapidly, and it is clearly congested. Figure 5.15 shows that the SMM is crowded at specific times and in specific

locations, all of which correspond to the real situation. This is because workers and students leave schools and businesses at the same time. Congestion starts to drop off after rush hour, then increases later due to work or study requirements. All of the eight junctions were completely jammed during the busiest peak time (0710). This is probably because school begins at 0715, universities are open from 0730, childcare facilities open from 0700, and many businesses and government offices open from 0730.

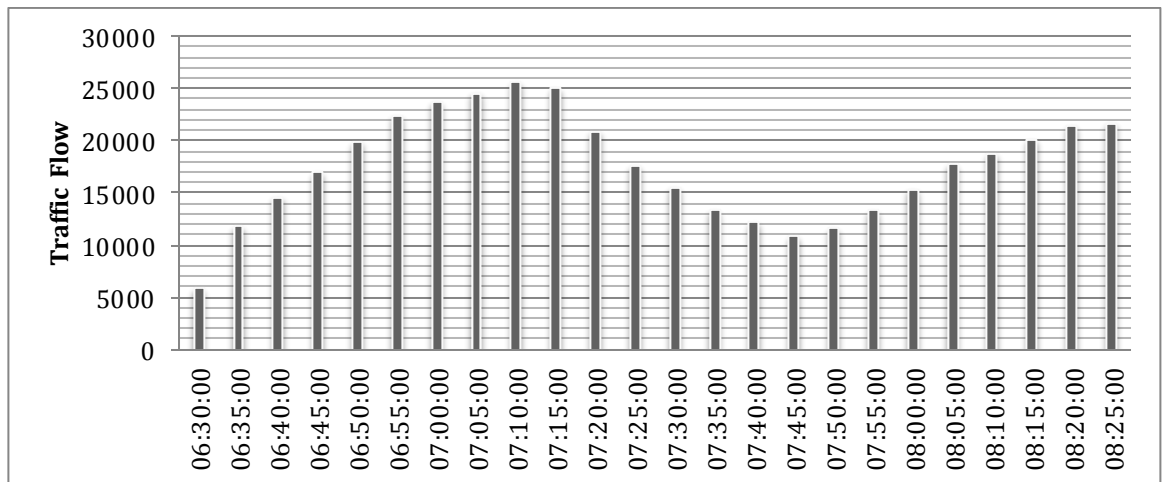


Figure 5.15 The worst congestion periods (time/car flow) (Original: Author)

5.5.3 Indicator 3: Journey time

Travel time, speed and delay are all travel time-based measures of system performance. Journey speed is a useful tool for normalising the travel time results into an index of overall system performance. Travel time may be accumulated in terms of vehicle hours travelled (which is the sum of all the travel times for all vehicles during the simulation period), or an average travel time may be reported. Some software will report the travel time by components. The microsimulation software reports time in units of seconds, minutes or hours.

Journey time costs are a large component of transport economic impacts, so how they are evaluated significantly affects planning decisions. Journey time is often worth more than monetary costs. Journey time costs are highly variable: a small portion of trips

have high time values, a large number have moderate to low time values, and some travel has zero or negative time cost (travel is a desirable activity).

For example, congested roadway and crowded transit travel tend to have a high time value since people making lower-value trips will avoid such conditions (T. Litman, 2009). SMM reports the time in seconds. Figure 5.16 displays time taken (seconds) for each five minutes modelled:

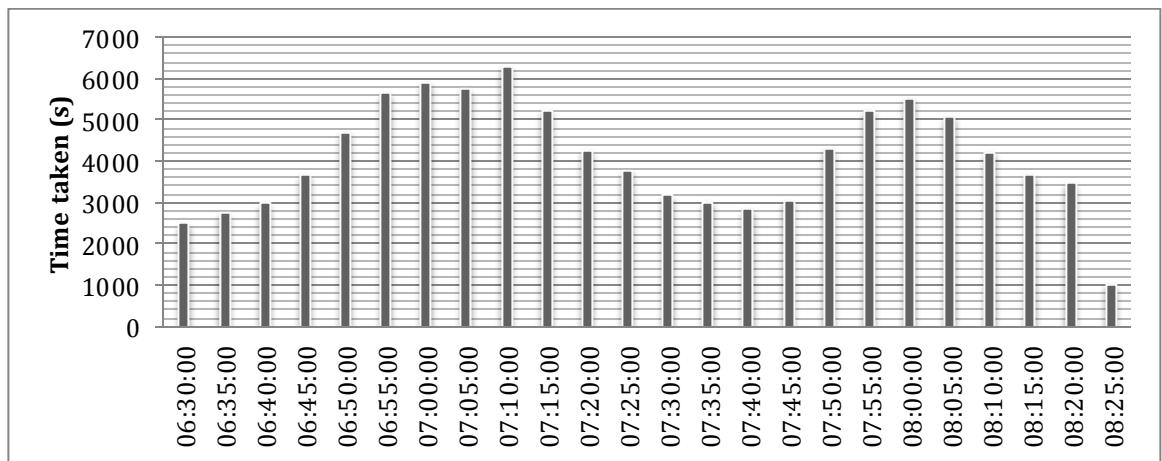


Figure 5.16 Worst congestion times (time/time taken) (Original: Author)

5.5.3.1 Time between destinations

Data analysis shows the statistics matrix for the time between the origins for each zone to the destination. The different strategies are displayed in Table 5.14 below:

Table 5.14 Time taken between destinations by seconds. Yellow= longest journey time, Red= shortest journey time for each column. (Original: Author)

Origin

	7	8	9	10	11	12	13	14	15	16	17	18	
Destination	7	144.13855	190.03169	288.01923	268.22145	560.51637	453.02893	636.21519	564.87719	590.45833	688.36667	116.43642	
	8	181.44928		74.71849	177.07143	260.78125	388.42623	466.10714	612.07595	577.55814	341.57403	404.66667	187.56894
	9	179.04508	97.38095		194.64497	322.23684	402.36641	507.82143	691.24561	621.5	361.875	434.78571	176.03916
	10	344.29298	182.93023	220.85593		159.73759	295.13806	349.6	518.97665	451.80198	243	305.93407	341.17485
	11	244.71831	236.32308	297.41706	141.85686		394.67151	278.33333	472	395.10526	405.33333	503.09615	230.77083
	12	526.23529	297.42553	356.90625	247.43571	338.64317		84.98987	478.96985	424.62045	171.3391	236.5011	555.65909
	13	464.42857	395.40244	509.55714	332.9621	270.05693	171.22589		343.17143	290.31132	338.94737	385.03797	452.95556
	14	602.28125	556.75	683	467.53521	421.11348	475.83871	291.21472		126.36554	953.75195	93.7639	595.13333
	15	601.34375	561.8	632.28571	460.08889	401.40714	446.02358	281.04938	123.83861		799.84184	438.39773	561.26667
	16	711.5625	341.12835	366	261.90909	474.35294	291.21854	432.5625	169.15429	105.73239		143.25452	757.08333
	17	746.83333	411.33333	497.25	349.2	640.79661	587.18509	505.77444	89.40504	315.52672	69.07595		725.75
	18	80.71429	130.06015	176.45827	288.73469	264.03922	551.35885	448.96552	630.22222	561.32143	558.91892	653.09574	

5.5.4 Indicator 4: Queue length

The typical characteristics of urban road travel are frequent stops due to congestion and intersections, and the associated delays. The major parameters used to quantify a signal's performance include queue length and delays experienced. Thus, information about the number of vehicles queuing and the associated delays are useful for devising traffic management strategies to help improve traffic network performance (S. Anusha and others, 2013). SMM results shows the queue length every five minutes, as shown in Table 5.15 for each junction:

Table 5.15 Queue length by metre for each line every five minutes. (Original; Author)

	OLS	KFRS	MOHE	MOHW	ORE	ORW	KAE	KAW	IME	IMW	OLN	KFRN
06:30:00	161.546	51.3419	156.642	87.9075	125.731	62.6884	0	114.979	203.114	68.8783	81.6912	57.8148
06:35:00	185.263	51.7313	155.256	107.476	234.141	84.7668	62.154	127.263	155.326	69.3057	98.0392	65.9389
06:40:00	157.092	55.0276	166.675	121.737	211.614	106.377	87.1071	213.971	142.759	102.81	84.5653	83.64
06:45:00	133.528	64.9251	270.154	119.725	175.005	131.82	103.157	199.199	180.663	184.127	155.06	72.5555
06:50:00	84.3534	57.9565	304.985	138.832	87.2399	121.262	107.965	212.723	185.759	223.928	130	111.759
06:55:00	127.519	55.7579	374.549	118.434	122.352	142.144	131.253	312.254	190.185	355.586	145.948	104.787
07:00:00	106.556	57.427	375.897	106.374	73.4555	114.829	159.951	335.765	184.979	585.881	185.513	204.635
07:05:00	95.4407	56.2401	333.46	98.5489	47.4436	120.398	132.755	210.548	248.296	449.587	147.396	318.32
07:10:00	105.397	60.3344	206.045	102.381	0	78.7185	126.236	191.995	440.307	370.767	107.127	425.329
07:15:00	107.437	51.0371	186.043	106.017	54.8015	82.4551	106.177	175.441	586.801	227.985	105.073	498.544
07:20:00	90.5064	73.7145	176.855	97.961	109.169	94.8802	96.9641	145.503	472.715	115.891	83.4375	572.24
07:25:00	92.7036	53.978	145.111	98.3614	147.512	73.7343	116.746	141.243	417.862	94.3125	87.7513	629.499
07:30:00	105.737	50.7862	134.494	130.988	230.857	72.0247	62.1656	144.178	198.611	68.2352	111.654	650.14
07:35:00	117.685	60.2438	167.182	143.911	263.662	77.2032	108.936	197.018	163.486	64.1028	79.8879	634.578
07:40:00	126.131	0	174.769	132.867	223.516	93.6436	120.143	222.574	112.092	61.6568	64.1804	494.555
07:45:00	156.256	0	136.933	168.574	259.369	122.566	182.264	209.737	133.759	70.4187	57.4726	352.198
07:50:00	113.187	44.0346	156.902	150.797	313.041	114.104	173.547	357.216	160.472	63.7408	58.5365	264.473
07:55:00	156.275	55.5124	269.56	122.345	318.704	118.573	193.938	378.821	123.922	70.0649	77.9576	143.226
08:00:00	140.252	62.851	266.021	141.421	309.136	100.285	252.017	373.675	118.818	75.7254	77.9994	103.886
08:05:00	113.906	56.24	201.421	137.84	231.51	134.238	156.605	399.708	111.092	105.817	119.887	102.304
08:10:00	109.837	57.9565	120.428	131.163	245.899	98.286	144.814	436.683	70.4298	97.9416	153.983	163.558
08:15:00	98.0586	55.6957	145.837	104.828	147.184	109.483	151.095	410.057	102.394	159.15	125.868	209.619
08:20:00	46.6714	57.2145	89.7564	116.507	128.616	106.014	115.14	454.809	160.316	157.191	116.324	225.218
08:25:00	60.9051	57.6739	94.2218	91.4523	196.68	86.2835	97.4359	402.643	151.436	201.113	104.316	356.714

5.6 Conclusions

This chapter contributes to research objective number four; to create and calibrate a Strategic Microsimulation Model (SMM) for the most congested part of Riyadh City Core. The specific research questions to be answered by this chapter are as follows:

Research question 10: To evaluate microsimulation as an approach to transport planning, the development of a microsimulation model of a transport corridor in Riyadh, and its calibration to live traffic situations.

The model has been created via Paramics microsimulation software since this helps to realise the aim of making both a theoretical and practical contribution to knowledge. Accordingly, nine major steps were implemented in an effort to achieve the necessary outputs from the model: Identification, Data collection, Coding, Error checking, Model creation, Calibration, Alternatives testing, Documentation and Presentation. SMM was calibrated via several steps to ensure the model was validated in line with current best practice for the industry. This includes a formal model audit performed by SIAS Ltd. One new way of visualising and modelling the complex interactions between policy interventions and individual transport user behaviours is to use traffic microsimulation in this way.

Research question 11: How can the SMM be used to reveal the structure and character of Riyadh's existing transport challenges?

The model itself is 1.3km by 7.4km, and simulates approximately 40,000 trips over a two-hour period between 0630 and 0830. SMM observation is an important feature of microsimulation, and one of its key benefits. It's a way of communicating complex system ideas and results to stakeholders. They can 'see' the emergent phenomena and

complexity with their own eyes. The results show that the main key features of existing network are:

- Substantial queuing (time) from King Fahd Road (KFR) to King Abdullah Road (KAR) and Imam Road (IR) inbound and outbound at 0715
- Substantial queuing (length) at KFR Northbound at 0730, the highest volume is on KFR, KAR and IM
- Most congested junctions are IM eastbound via KFR, and KAR westbound via KFR at 0705
- Most congested lanes are Lanes 1 and 2 of KAR and Lanes 1 and 2 of Mohammed Street (MOH) + Lanes 1, 2, 3, and 4 of IM travelling towards KFR at 0710.

Research question 12: To consider the role of such models in exploring and visualising larger-scale policy interventions, and communicating them effectively to stakeholders.

The microsimulation model allows to imitate the real life of the existing road network. This simulation provides a broad and comprehensive view for stakeholders to consider the problems of the current network and what are the likely consequences if any policy is taken (For example, policy transfer issues: see question 14).

Microsimulation captures the behavioural aspects of transport networks and allows them to be observed, and as such has proven invaluable in studies of ITS facilities and strategies, changing land use patterns, junction design, signal timing and much more, including policy transfer effects. Indeed, one identified research need in the policy transfer literature is for new modelling approaches, and the SMM responds to that need. Yet this exciting tool currently lacking in Riyadh.

The vehicles within the model are endowed with behaviours (such as their origin/destination, speed, following distance etc.) and allowed to interact with each other on a digitally modelled road network that is geometrically referenced to the real thing (Brien et al., 2015).

Traffic microsimulation is a test bed upon which to evaluate current and future scenarios and help planners and decision makers via a digital imitation of real-world traffic. In the next chapter, SMM performance indicators will be developed to produce high-level characterisations of the Riyadh City Core's road network. The different stakeholder-defined scenarios will then be examined with regard to the overall network characterisations, and their effectiveness assessed.

CHAPTER 6 Characterising the performance of Riyadh's road network using Overall Performance Curves (OPCs)

6.1 Introduction

Having justified the use of the microsimulation model and described its design and calibration in Chapter 5, this chapter moves on to put the model to use. Microsimulation is more typically used for operational and tactical problems, but in this research it is being used in a new way as a strategic tool. Riyadh's road network will be characterised against the 'indicators' described in Chapter 5 under all possible conditions, from free-flowing traffic to the point of complete network saturation. These indicators are:

- Level of Service (LoS)
- Traffic flow
- Journey time
- Queue length

After each model iteration, the values of the respective indicators will be logged and these, in turn, will represent coordinates for so-called Overall Performance Curves (OPC). These have been developed in this thesis as a graphical representation showing how the network performs under all conditions.

The effects of future scenarios and their potential implementation on Riyadh's road network can be placed on these curves and conclusions drawn. With the network thus characterised, it becomes possible to scrutinise the expected and actual outcomes to be derived from the range of future scenarios gained from key Riyadh transport stakeholders.

This chapter briefly describes how this form of novel analysis fits into the larger realm of strategic road network analyses, details the method used to derive the OPC curves, and also presents the OPC curves themselves.

6.2 Methods

6.2.1 Design

Overall performance curves are created by running the SMM multiple times with a different car volume matrix (Origin-Destination matrix, see Table 6.1) at each model iteration. This enables the effects of all possible scenario assumptions on the network to be visualised. In practice, this was achieved by increasing the underlying OD matrix values from 0 car volume to 100% additional car volume in 10% increments.

The resulting values of each indicator (e.g. LoS, traffic flow, travelling time and queue length) are plotted in order to create the OPC curves. This means the SMM has been run more than 100 times under all traffic conditions, from a completely empty network to a completely saturated one. Table 6.1 below shows the total volume of vehicles within the SMM at all iteration points.

Table 6.1 The total amount of at all matrices (Original: Author)

Matrix percentage compared with current situation	Car volumes
-90%	3981
-80%	7963
-70%	11944
-60%	15926
-50%	19907
-40%	23889
-30%	27870
-20%	31852
-10%	35833
Current	39815

10%+	43796
20%+	47778
30%+	51759
40%+	55741
50%+	59722
60%+	63704
70%+	67685
80%+	71667
90%+	75648
100%+	79630

6.2.2 Material

Paramics microsimulation allows the user to reset the car matrix on the network. This was done according to the values shown in Table 6.1. A total number of 39,815 cars were travelling within the study area in the base model (the current situation) between 0630 and 0830 (the morning peak). The number of cars within the study area was then increased/decreased sequentially from 10% to 100%, again compared with the current situation. The OPC coordinates were determined when X= car matrix percentage of the current situation, Y= indicator unit (see results section).

It was noted that when vehicles within the network exceed 30% of the current situation, the network did not allow more cars to enter the network due to their inability to depart from the zone of origin. The percentage of unreleased vehicles reaches 39% when the car matrix reaches 30% at the worst point of the morning peak (i.e. 0810). This seems to indicate the base model represents an already heavily loaded network.

6.3 Results

As mentioned above, this process aims to create a defined network performance curve at the strategic level to study the impact of all policies on the same test bed. The following sections present the results of the four network indicators under all possible network conditions.

6.3.1 Indicator 1: Level of service (LoS)

6.3.1.1 Level of Service for KFR (King Fahd Road)

Since its inception in 1965 by the Highway Capacity Manual (HCM), Level of Service (LoS) has proven to be an important and practical 'quality of service' indicator for transportation facilities around the world. The LoS has a grading system for traffic operating conditions on a road network using six delay-based indicators or levels (ordered from best to worst conditions): A, B, C, D, E and F. LoS rating has its foundations in quantifiable measures of effectiveness and road users' perceptions: together, these define an LoS based on acceptable traffic operating conditions for the road user, implying that traffic safety is inherent to this definition (Almonte et al., 2010).

In Chapter 6, the SMM shows that the LoS for King Fahd Road (KFR), the main freeway in the study area, is 1.52 in the current situation, which is an LoS rating of F. As shown in Table 5.11, the LoS according to British standards are:

- $A > 0.35$ volume/capacity ratio.
- $B > 0.55$ volume/capacity ratio.
- $C > 0.77$ volume/capacity ratio.
- $D > 0.92$ volume/capacity ratio.
- $E > 1.0$ volume/capacity ratio.
- $F < 1.0$ volume/capacity ratio.

Figure 6.1 shows the LoS for all traffic conditions, and highlights the current situation on the KFR. The road user would typically experience an LoS of F as 'heavy, slow-moving traffic'.

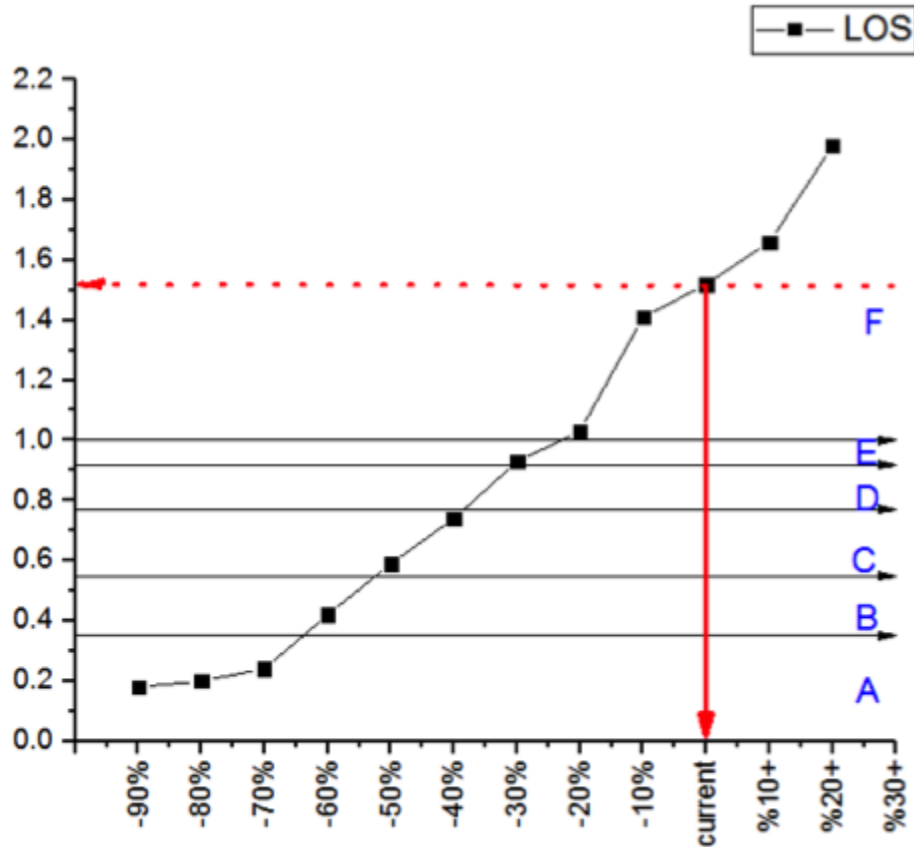


Figure 6.1 Changes in the LoS indicator for the King Fahd Highway under different traffic volumes (Original; Author)

As detailed in Chapter 5, the LoS grade within the study area has an inverse relationship with the O/D matrix. As the volumes in the O/D matrix decrease, LoS should increase. As shown in Figure 6.1, KFR will reach an LoS of A if the O/D matrix is reduced by a substantial 65% of its current status. This means stakeholders, in particular the public, must be aware of what a high LoS rating actually entails: a very substantial and unrealistic reduction in traffic volumes. A reduction of 65% will provide a road that is considerably more pleasant to drive on, but it would also represent a road that is over-engineered and operating below its economic capacity.

A particular feature of the LoS OPC curve for the KFH is a marked curvature of between -10% and -20% of the O/D matrix.

In other words, while there is an inverse relationship between O/D matrix volumes and the LoS, that relationship is non-linear. In the location identified, small changes in traffic volumes have disproportionately large effects on LoS. This means the network reaches an LoS of E if the O/D matrix is reduced by 20% or more. This is a meaningful improvement for a 'relatively' small decrease in volumes. This is a decrease that lies within the projected values to be derived from the new Riyadh Metro when it becomes operational.

6.3.1.2 Level of service for signalised junctions

This section broadens the analysis of LoS from considering just one corridor to examining all of the major signalised junctions within the study area. Within this area, there are eight junctions, named alphabetically as shown in Figure 6.2:

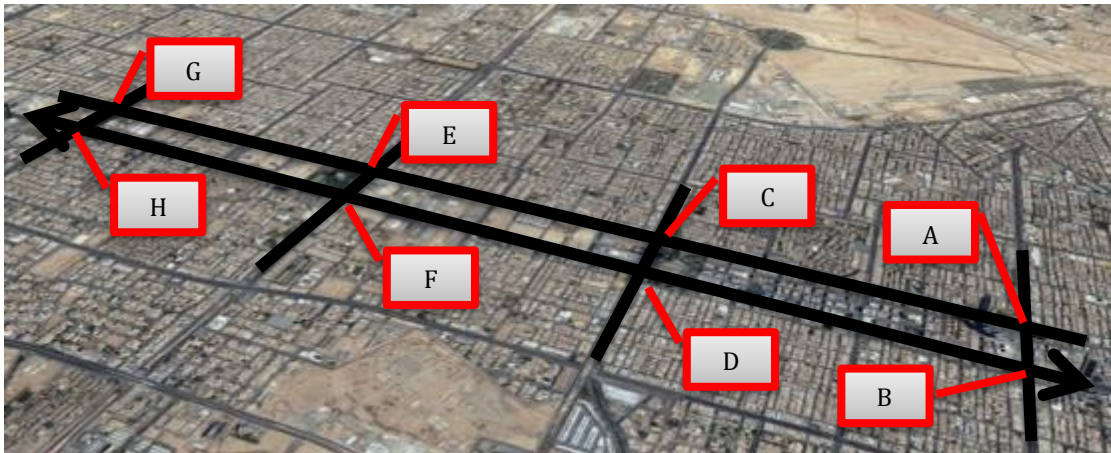


Figure 6.2 Key junctions within the study area labelled as follows: A: OL and MOH, B: KFR and MOH, C: OL and OR, D: KFR and OR, E: OL and KAR, F: KFR and KAR, G: OL and IM, H: KFR and IM

The same methods explained above in Section 6.2 were applied to create OPCs for all of the labelled junctions in the study area. The OPCs show that all junctions, like the main arterial roads, were still in the F-grade LoS area until at least 60% of the vehicles

were removed from the car matrix. All are busy under current traffic conditions, although clearly some are busier than others.

Figure 6.3 presents level of service for all junctions in the study area, which were named alphabetically above in Figure 6.2. What is interesting is the way the OPCs' profiles differ. Junction D, for example, seems particularly sensitive to reductions in traffic flow around the 40% mark. Junctions A, E and H are quite close to something approaching a viable economic capacity with LoS grades below F, whereas Junction B is a long way from achieving anything other than an LoS of F. The curves seem to indicate a priority rating for which junctions may require urgent attention.

As shown in Figure 6.3, the junctions also suggest signalling strategies that could be usefully explored. Junction B, by far the busiest, lies next to Junction A, which carries one of the lightest loads. Perhaps there are ways for these junctions to 'share the load' a little more equally. Figure 6.3 shows OPC for all junctions in the study area

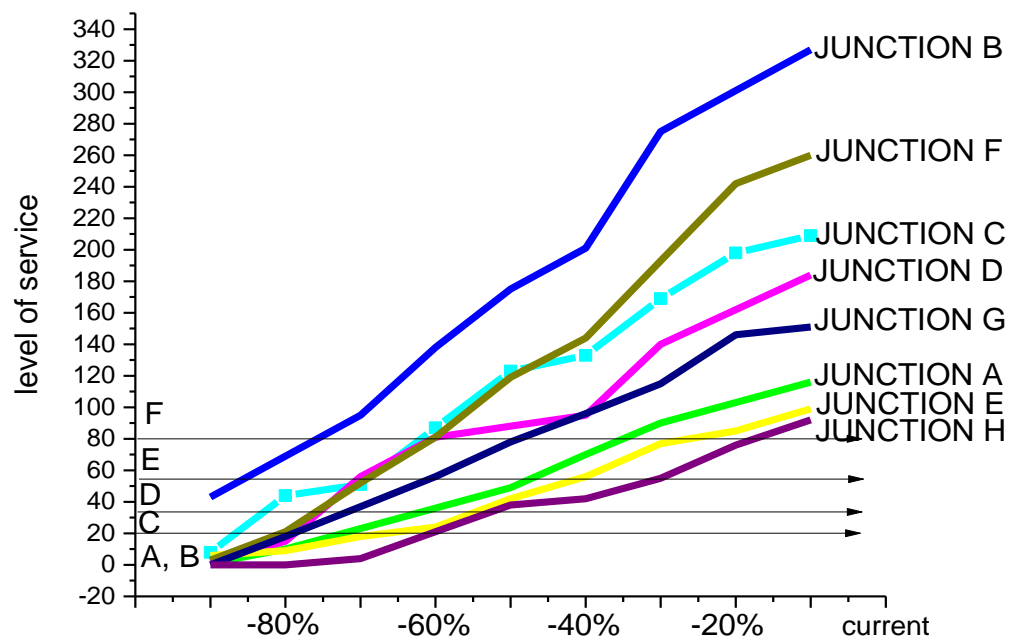


Figure 6.3 OPC for all junctions in the study area (Original: Author)

6.3.2 Indicator 2: Traffic flow

The second indicator extracted from the SMM is traffic flow. This refers to the average volume of vehicles travelling across the network from specific origin to a particular destination over a given period of time (as defined in Chapter 5.) According to the model, current traffic conditions are characterised by two ‘humps’ in vehicle flow, one at 0710 and the other on 0820.

As discussed in Chapter 5, these reflect commuting times for schools and businesses, with network demand falling at other times. It’s interesting to speculate whether some of the worst traffic conditions on the network could be significantly alleviated by managing demand and smoothing the peaks in traffic flow, for example, with the widespread introduction of flexible working hours, staggered business start times, different school arrangements etc. In the absence of this, by decreasing the number of cars in the O/D matrix, the network’s flow profile changes in the way shown in Figure

6.4. With no changes to the underlying demand profile, it appears vehicle flow rates fall relatively smoothly and linearly as vehicles on the network decrease.

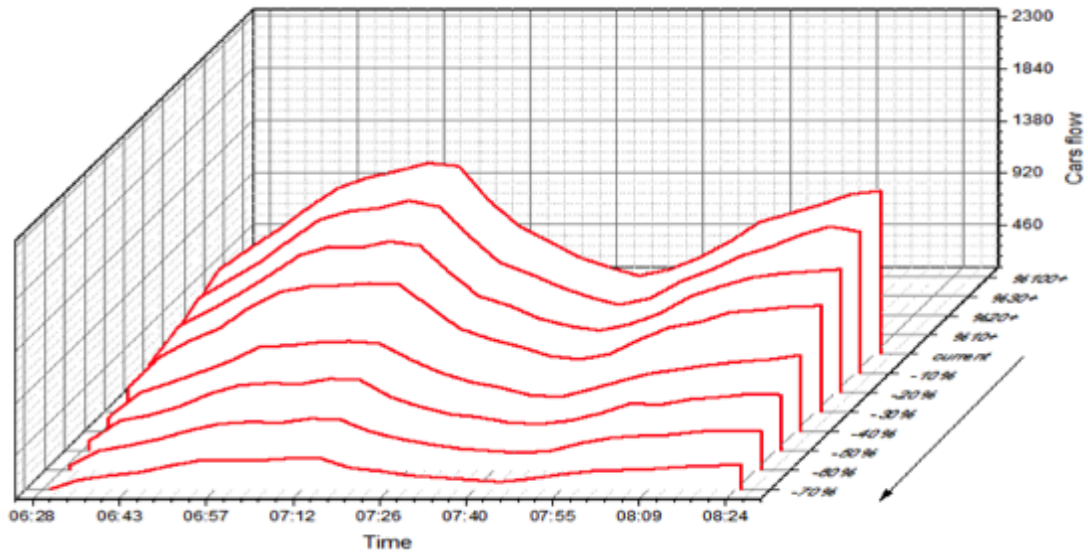


Figure 6.4 Reducing traffic flow within the Riyadh City Core under different levels of demand across the morning peak (0628 to 0824) (Original: Author)

To an extent, there is a positive relationship between the volume of cars on the O/D matrix and the resulting flow on the network. The more cars in the matrix, the greater the overall flow. As shown in Figure 6.5, the O/D matrix was reduced from its present level in 10% decrements to - 70%. This consistently reduced traffic flow at the congested time of 0710, for example, from 1600 to fewer than 300. This is in line with the predictions made by the Greenshields model. Staying with this consistency, it would also be expected that as volumes in the O/D matrix increase further, a point will be reached at which flow rates start to decrease. This is because the network becomes saturated and vehicles start to have difficulty entering the modelled zone. Increases in traffic volumes above the current situation are presented in Figure 6.5.

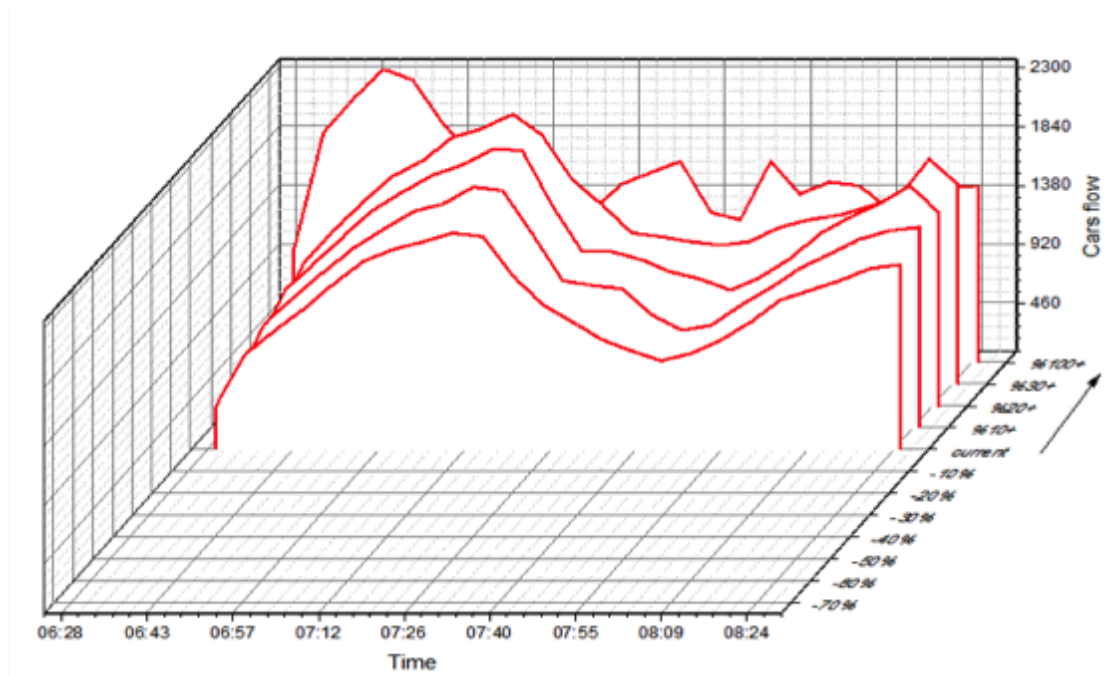


Figure 6.5 Increased traffic flow within Riyadh City Core under different levels of demand across the morning peak (06:28 to 08:24) O/D matrix of cars flow (Original: Author)

Overall, it appears that a comparatively modest increase in volumes of more than 30% (forecasted to arrive in 2021 under current predictions) leads to significant difficulties. When 30% extra traffic volume is added to the O/D matrix, the SMM starts to hold the traffic behind the car released zone (the SMM releases vehicles automatically within the network – as explained in Chapter 5). In other words, no further vehicles can enter the network because it is full.

As seen in Figure 6.6, with a doubling of vehicles in the network (plus 100%), the vehicle flow line starts to increase from the beginning of the simulation (0630 on an empty network) through the release of 2840 vehicles, decreasing at 0642 (just 12 minutes later) because further vehicles can't be released onto the network (see Figure 6.1). Complex effects such as these represent some significant real-world issues. In practice, it would represent extremely long queuing times in other parts of the city as vehicles struggled to enter the study zone, alongside a range of secondary, large-scale city-wide implications.

6.3.3 Indicator 3: Journey time

The third indicator extracted from the SMM is travel time. This is the mean number of journey times between all origins and destinations. As mentioned in the previous section, current traffic conditions are characterised by two 'humps' in vehicle flow, one at 0710 and the other at 0820. These are the most congested times on the network, and this is reflected in journey times. At these times, a vehicle will take an average of approximately 98 minutes (5900 seconds) to reach their destination. The average distance between destinations is 5.3 km. This means the average speed on the network is just 18.4 km/h.

When reducing the O/D matrix in 10% stages, the travel time curve shows a positive relationship: having fewer vehicles in the O/D matrix, leads to improved journey times (and flows – see above). Figure 6.6 shows that travel time rates drop relatively smoothly and linearly as vehicles on the network decrease. Again, according to the Greenshields model, this is to be expected.

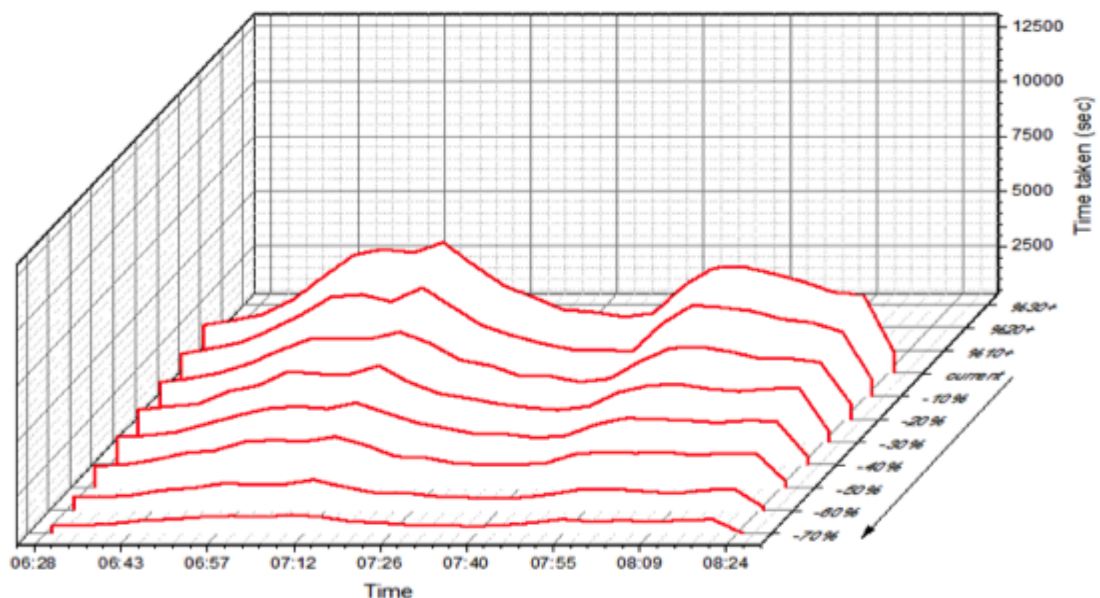


Figure 6.6 Mean journey times for Riyadh City Core. Reducing traffic volumes in 10% stages reduces overall journey times. (Original: Author)

As seen in Figure 6.6, travel time decreases from the 98 minutes (5900 seconds) of the current situation to less than 17 minutes (1000 seconds) on average if the O/D matrix

decreases by 70% of its current status. A reduction of 70% is unlikely to represent an economically viable use of an expensive transport asset, but quite significant reductions in journey time seem achievable with much more modest volume reductions.

At -10%, for example, journey times decrease from 98 minutes to 87 minutes and 52 seconds, a saving of 10 minutes and 52 seconds. At minus -20% (a reduction expected when the Riyadh Metro becomes operational), journey times improve further to 71 minutes and 46 seconds. Perhaps more interesting is what happens when vehicle numbers increase from their present level as shown below in Figure 6.7:

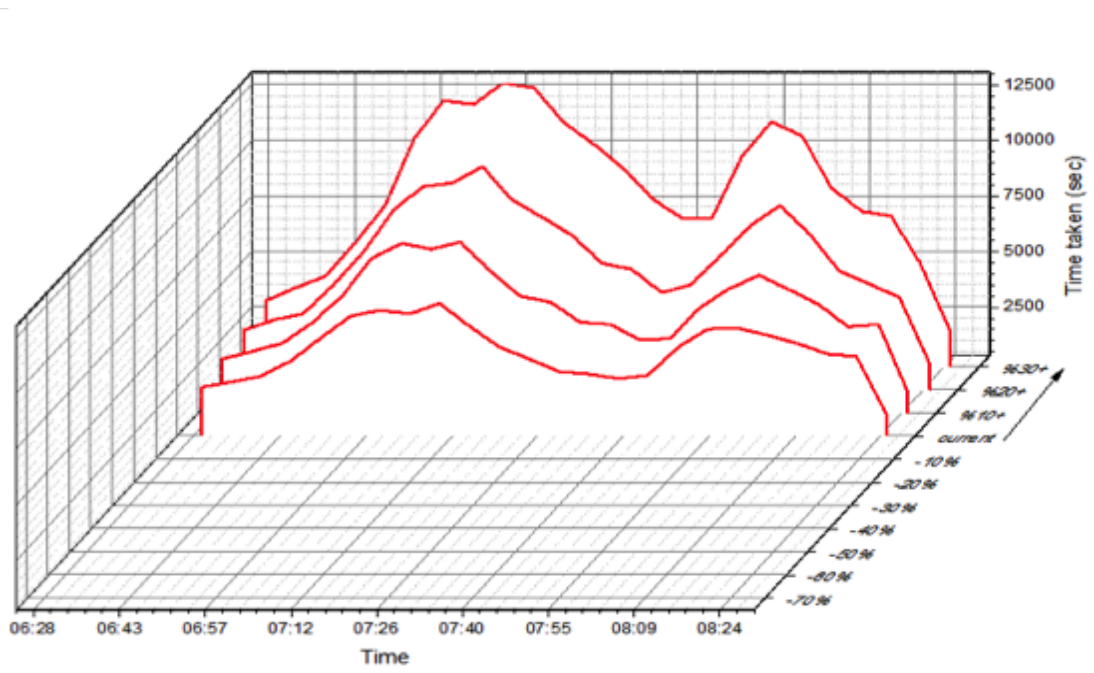


Figure 6.7 Mean journey times for Riyadh City Core. Increasing traffic volumes in 10% increments reduces overall journey times. (Original: Author)

In the absence of any intervention, Riyadh's traffic is forecast to increase (Chapter 2). Figure 6.7 shows the effect this would have on journey times. A 10% increase in traffic volumes leads to a substantial increase in average journey times from 98 minutes to 133 minute and 49 seconds. A pronounced feature of the results is the way the two 'peaks' (corresponding to school and work journeys) become increasingly amplified.

With 30% more traffic – a realistic prospect in the next four years if no intervention is made – journey times at the school peak increase by more than 220% from 98 minutes

to more than 209 minutes. The results seem to indicate, once again, that Riyadh's current traffic situation is quite acute. Even modest further increases in traffic would worsen conditions dramatically.

6.3.4 Indicator 4: Queue length

Queuing is the subject of extensive study within transportation engineering (S. Anusha et al., 2015). Queues are defined as “the accumulation of vehicles in a specific lane due to road conditions” (S. Anusha et al., 2015). The queuing process is an expression of the rate at which vehicles arrive at the back of a queue, the rate at which they travel through the queue, and the rate at which they exit from the front of it (Kozlov et al., 2014). Queues, like LoS, play a significant role in how network road users experience performance. Queues can also be a significant source of lost productivity, increased emissions and other problems (Kozlov et al., 2014).

In the present case, the mean queue length is 164 metres, decreasing to 98 metres at –40%, reaching 56 metres by –70%. To put this in context, a 108-metre queue would take the average driver approximately 81 minutes to traverse. By decreasing the number of vehicles in the O/D matrix, the queue length indicator describes a similar relationship with the other indicators. A positive relationship was seen when the volumes in the O/D matrix were reduced (Figure 6.8) and increased (Figure 6.9).

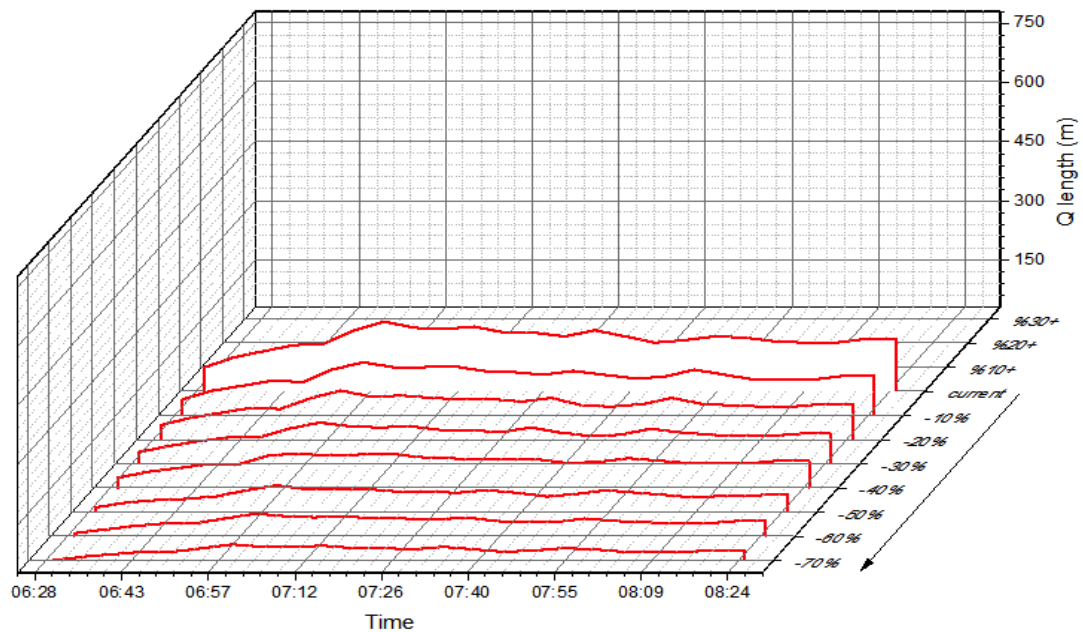


Figure 6.8 Mean queue length for Riyadh City Core. Reducing traffic volumes in 10% stages reduces overall queue length (Original: Author)

Queue length reduces noticeably from 164 metres to 131 metres (-12%) at the current most congested time (0710) if the car matrix is reduced by 10%. Figures 6.8 and 6.9 show the effect of this on queue length. The same two 'peaks' of other indicators become increasingly noticeable. Removing 30% of additional traffic queue length at 0710 reduces the queue by 65% from 164 metres to 108 metres. Overall, queue length rates fall relatively smoothly and linearly as vehicles on the network decrease. This follows the same trend as the previous indicators and O/D matrix.

In contrast, queue length increases rapidly with rises in underlying traffic volumes. A 10% increase sees queue length jump from 164 to 185 metres. At +20%, it jumps by a further 110% to 293 metres. If the O/D matrix increases by 30%, a level of traffic growth forecasted by 2021 if no remedial action is taken, queue lengths increase by 368% to 604 metres (more than half of a kilometre on average). Figure 6.9 shows the strongly non-linear growth in queue length between +20 and +30% of existing network demand. This suggests the network reaches a critical point at which it becomes highly sensitive to relatively small further traffic increases. If no measures are taken, these

increases in demand are forecast to occur in approximately four years' time, a situation which must clearly be avoided.

■

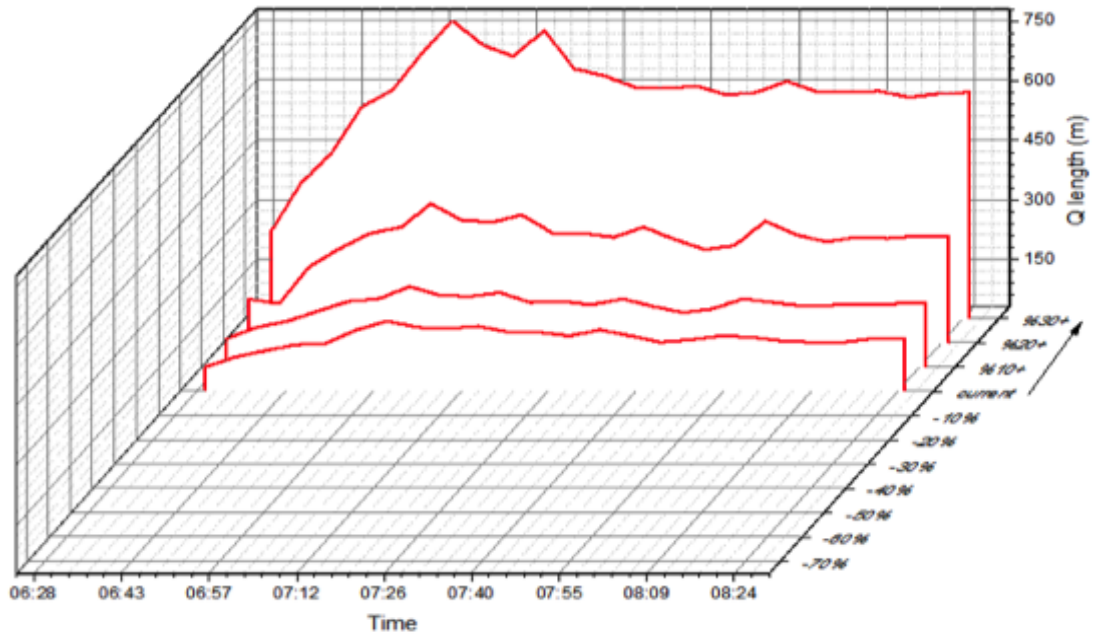


Figure 6.9 Mean queue length for Riyadh City Core. Increasing traffic volumes in 10% stages increases overall queue length (Original: Author)

6.4 Creating the OPC curves

The Overall Performance Curve OPC is the mean value covering the full peak for each indicator across all vehicle volume levels. By aggregating these values, the final output becomes a unified curve the impact of any proposed scenario on the network. Essentially, an OPC helps the planner to examine all strategies within same test bed to assess the effectiveness of their decision. The following sections describe the OPCs for each individual indicator.

6.4.1 OPC for Indicator 1: LoS

Figure 6.10 below shows the OPC curve for LoS where X= percentage of O/D car matrix amount against current car matrix and Y= LoS grade in terms of the volume to capacity (v/c) ratio. Overall, it can be noted that there is an inverse relationship between

the traffic volume (car matrix) and the LoS. This relationship goes through two main curvature regions. The fastest rates of change in the LoS occur between -10% and -20%, the slowest between -70% and -90%. The current situation seems to lie on the boundary of the fastest changing region, suggesting that relatively modest reductions in car flow will have the biggest initial impact. Beyond -30%, however, reduced traffic volumes have less pronounced effects on the LoS, and cost proportionately more to achieve.

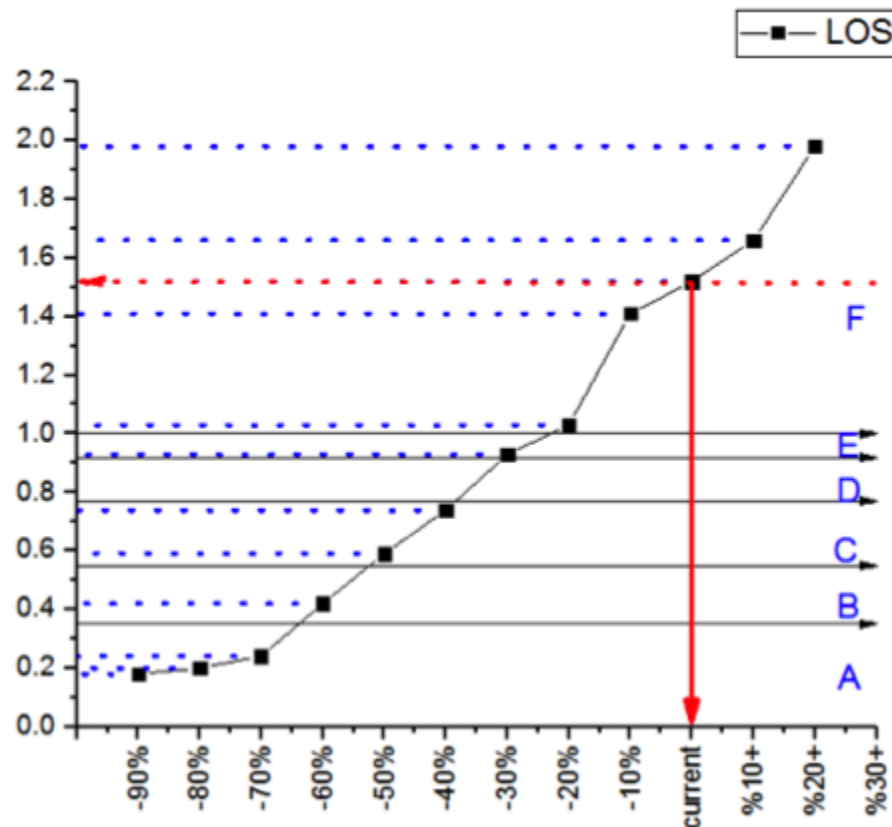


Figure 6.10 Overall Performance Curve (OPC) for the Level of Service (LoS) indicator (Original: Author)

6.4.2 OPC for Indicator 2: Traffic flow

Figure 6.11 shows the OPC for traffic flow. It can be noted that there is a critical curvature between -30% and -40%. This is the area where the greatest extent of change in the curve happens: when the matrix is reduced to 40%, traffic flow reduces from 835 to 620 vehicles with just a 10% reduction of the O/D matrix (the red circle refers to critical change). Other parts of the curve are more gradual. To strategise about future transport needs, these fast-moving areas of the curve, i.e. those most sensitive to

changes in vehicle flows, are the ones to target. This is because further (and potentially expensive) reductions will yield proportionately less effective results.

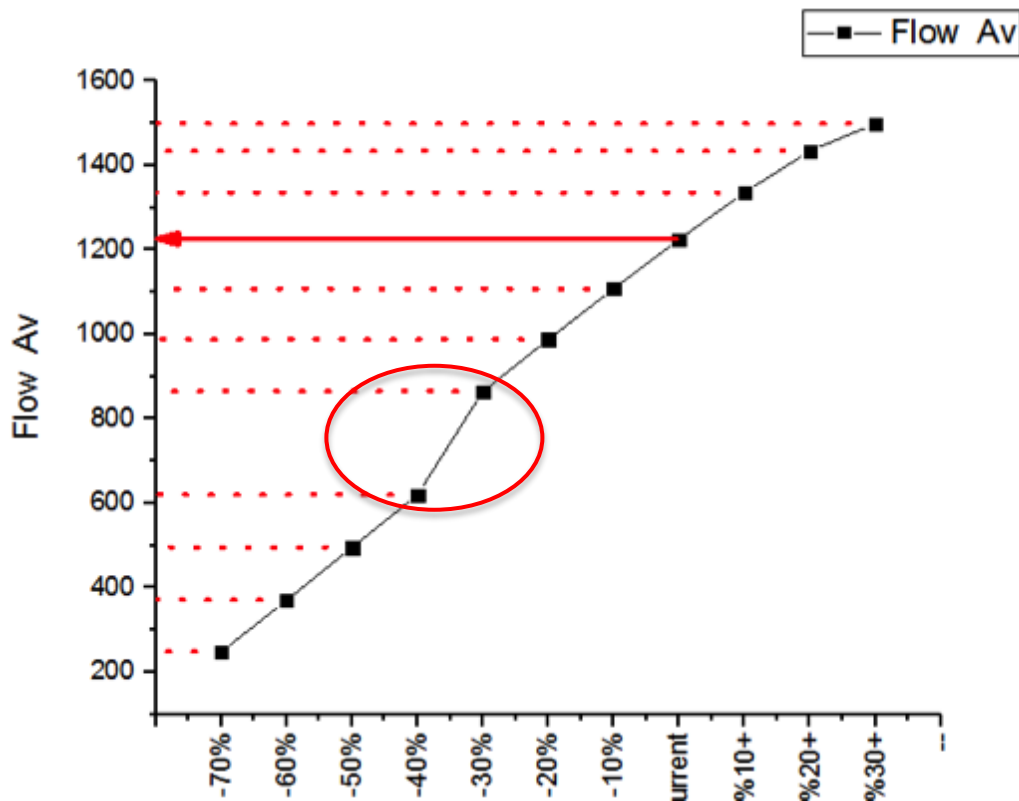


Figure 6.11 Overall Performance Curve (OPC) for the traffic flow rates indicator (Original: Author)

6.4.3 OPC for Indicator 3: Journey time

As shown in Figure (6.12) below, the relationship between traffic volume (as per the O/D matrix) and travel time is an inverse one. The curve begins to decline gradually as traffic volume reduces. From the OPC, it can be seen that travel time reduces from 1 hour 9 minutes and 4 seconds to 42 minutes and 23 seconds (saving 61% of the average time) when 30% of traffic volume is removed from the network. This is a significant number. Perhaps more importantly for the purposes of future policy, travel time doubles when 30% more vehicles are introduced on to the network. This is forecast to occur in four years should no action be taken. Overall, the journey time curve shows an upward trajectory, with increases in traffic volumes leading to increasingly disproportionate longer journey times. It appears that the current situation sits at an 'elbow' in the curve,

at which further increases in volumes will make journey times significantly longer than might have been the case previously.

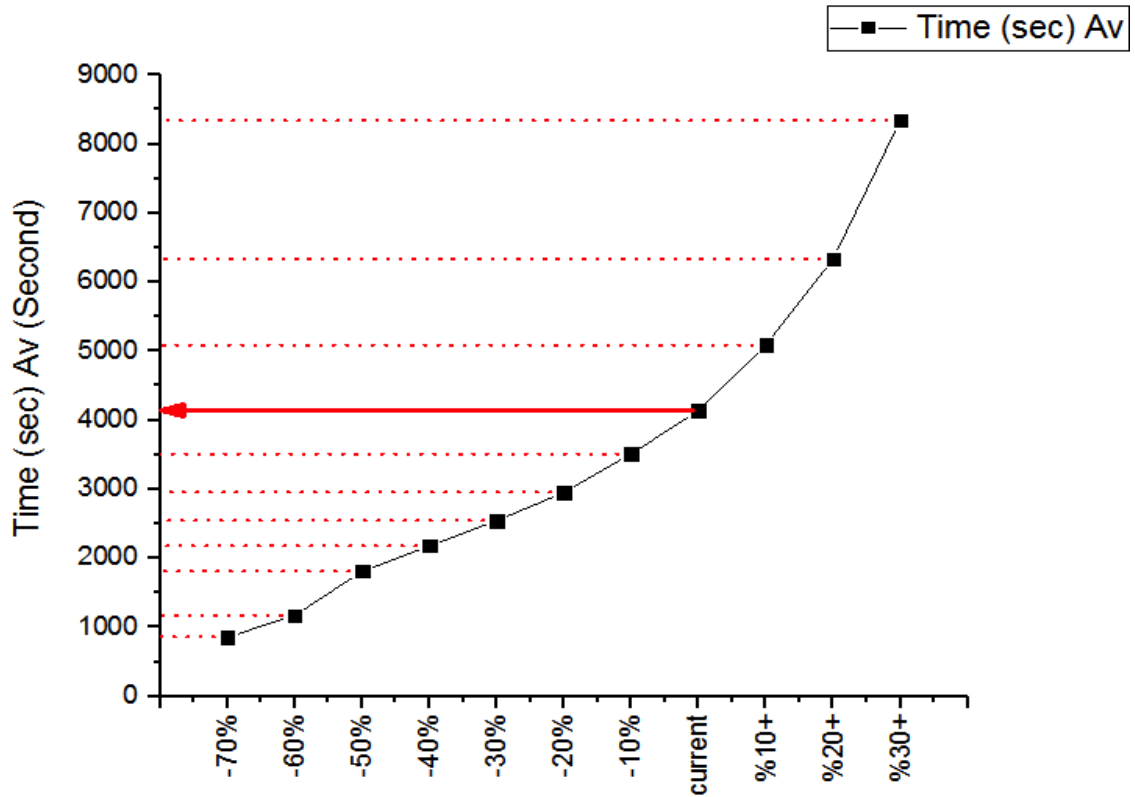


Figure 6.12 Overall Performance Curve (OPC) for the journey time indicator (Original: Author)

6.4.4 OPC for Indicator 4: Queue length

As seen in Figure 6.13, the OPC for queue length shows that the curve has a gradual curvature when traffic volume (O/D matrix) is reduced. The curve region between the current situation and 10% has a steeper gradient than that of between 50% and 40%. In contrast, the OPC shows a rapidly increasing mean queue length when traffic volume increases beyond the current level. For example, when volumes on the current network are increased by 30%, the mean queue length accelerates by 300%. As already noted, an increase of 30% is not implausible. Indeed, it is forecast to occur in approximately four years according to current estimates, should remedial action not be taken.

It should be noted, however, that it is highly likely that secondary effects will start to emerge well before then as queue lengths become intolerable for transport users (e.g. people and businesses may start to relocate and/or other unplanned and potentially injurious changes may start to happen). This is the strongest indication yet that the network, under present conditions, is in a critical state. A relatively small increase in traffic volumes, one forecast to occur in just four years' time, will be sufficient to yield a disproportionate and unacceptable increase in queue lengths.

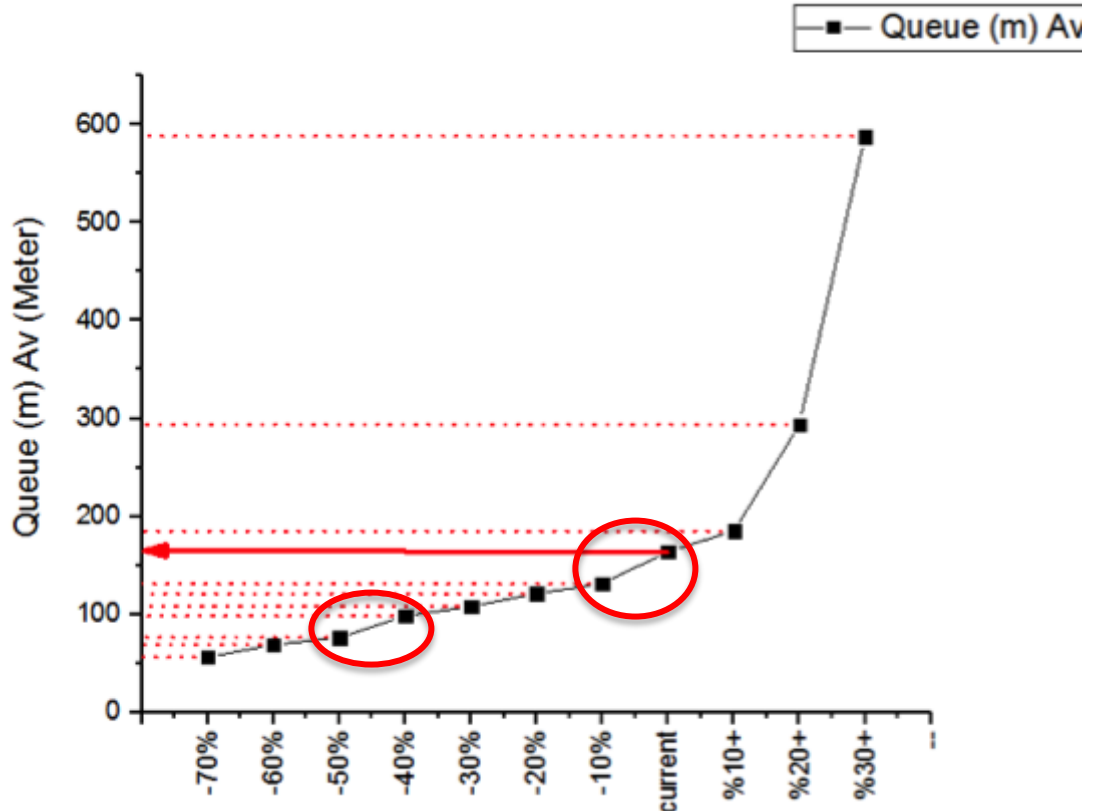


Figure 6.13 Overall Performance Curve (OPC) for the journey time indicator (Original: Author)

6.5 Discussion

In this chapter, the congestion indicators developed in Chapter 5 were modelled using the SMM and plotted into OPC curves. These indicators are: a) Level of Service (LoS), b) Traffic flow, c) Travel time and d) Queue length. OPCs of the study area provide a wide range of useful and interesting diagnostics. Principal among these are the twin findings that a) the curves are non-linear and changes to total car volumes will have

disproportionate effects on the key indicators, and b) the network is already in a critical state and highly sensitive to future increases in vehicle volumes.

Figure 6.14 presents the final aggregate OPC for all indicators. This is a graphic characterisation of how Riyadh City Core performs under a wide range of conditions, including those anticipated to occur under all conceivable future transport scenarios. This representation is designed to be a valuable diagnostic aid for all future thinking and reasoning about Riyadh's future transport strategy. This approach could be used for any other city anywhere in the world.

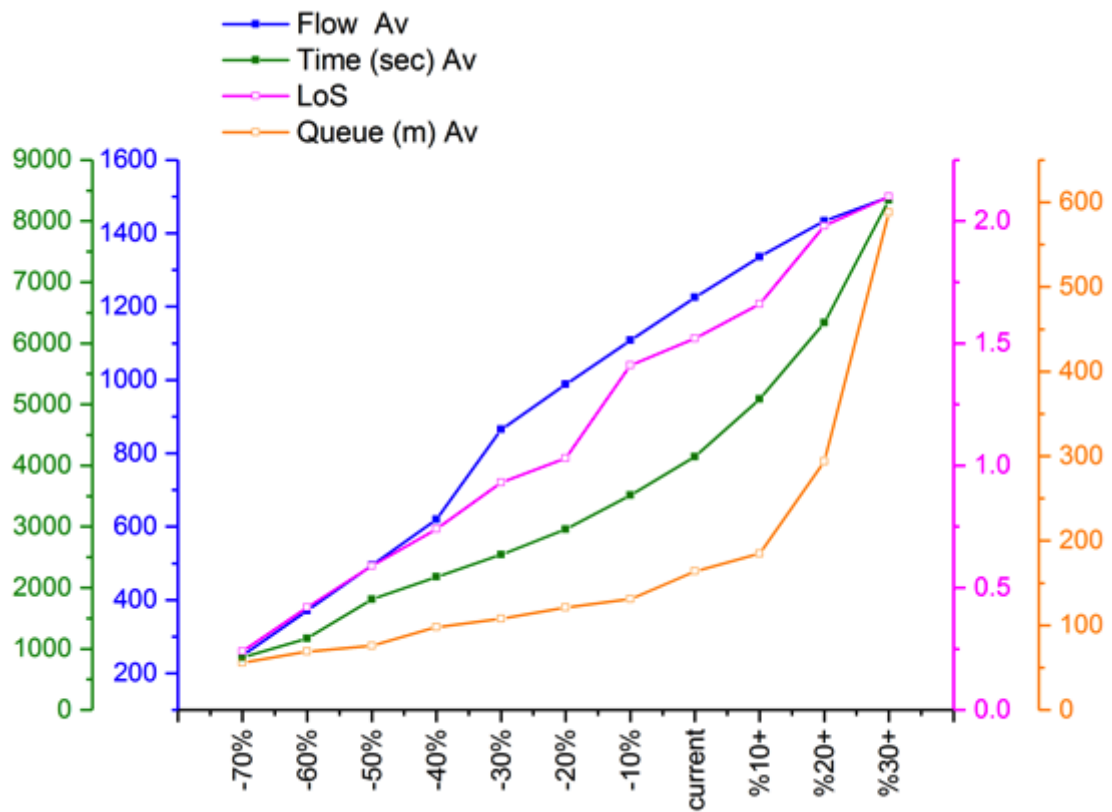


Figure 6.14 Final Overall Performance Curves (OPCs) of indicators for Riyadh City Core under different conditions presented in 10% values of current traffic volumes from the empty network until fully saturated (Original: Author)

Overall, the three primary OPCs show an inverse relationship between car volumes and LoS, flow, travel time and queue length. As car volumes increase, performance on these metrics, generally speaking, decreases. Importantly, however, in all the curves there is a critical point where the most rapid changes in the indicators occur. This is vital

information in the context of large-scale infrastructure improvements and policy interventions. These 'fast-moving' parts of the curves are where interventions will have the greatest effect. Other regions of the curves will respond more slowly for any given cost input.

Understanding how transport network performance varies under different traffic conditions is an essential factor in evaluating network conditions and in formulating further potential for improvement. The OPCs show that Riyadh's existing network is already in a critical state, with only small further increases required to worsen the current situation dramatically in some areas.

6.6 Conclusion

This chapter contributes to the overall research objective by creating Overall Performance Curves (OPCs) which characterise Riyadh's road network performance. The specific research questions the current chapter answered were as follows:

Research question 13: To what extent can the OPCs measure future scenarios on Riyadh's road network in comparison with the current status?

OPCs of the study area provide a wide range of useful and interesting diagnostics. Principle among which are the twin findings that a) the curves are non-linear and changes to total car volumes will have disproportionate effects on the key indicators and b) the network is already in a critical state and highly sensitive to future increases in vehicle volumes. This is a graphical characterisation of how the Riyadh city core performs under a very wide range of conditions, including those anticipated to occur under all conceivable future transport scenarios.

This representation is designed to be a valuable diagnostic aid for all future thinking and reasoning about Riyadh's future transport strategy. It is also an approach which could be used for any other city. OPCs are graphic representations showing network performance under all conditions. The effects of all future scenarios and their potential

implementation on Riyadh's road network can be placed on these curves and conclusions drawn.

Research question 14: What does Riyadh look like under all possible traffic conditions?

The OPCs show an inverse relationship between Origin / Destination OD matrix volumes and performance on the indicators. This relationship is going to worsen when car volumes in the OD matrix increase. As shown in the following figure, the increase in the OD matrix has a rapid impact on OPCs, especially, the queue length which is almost double the current situation and the journey time.

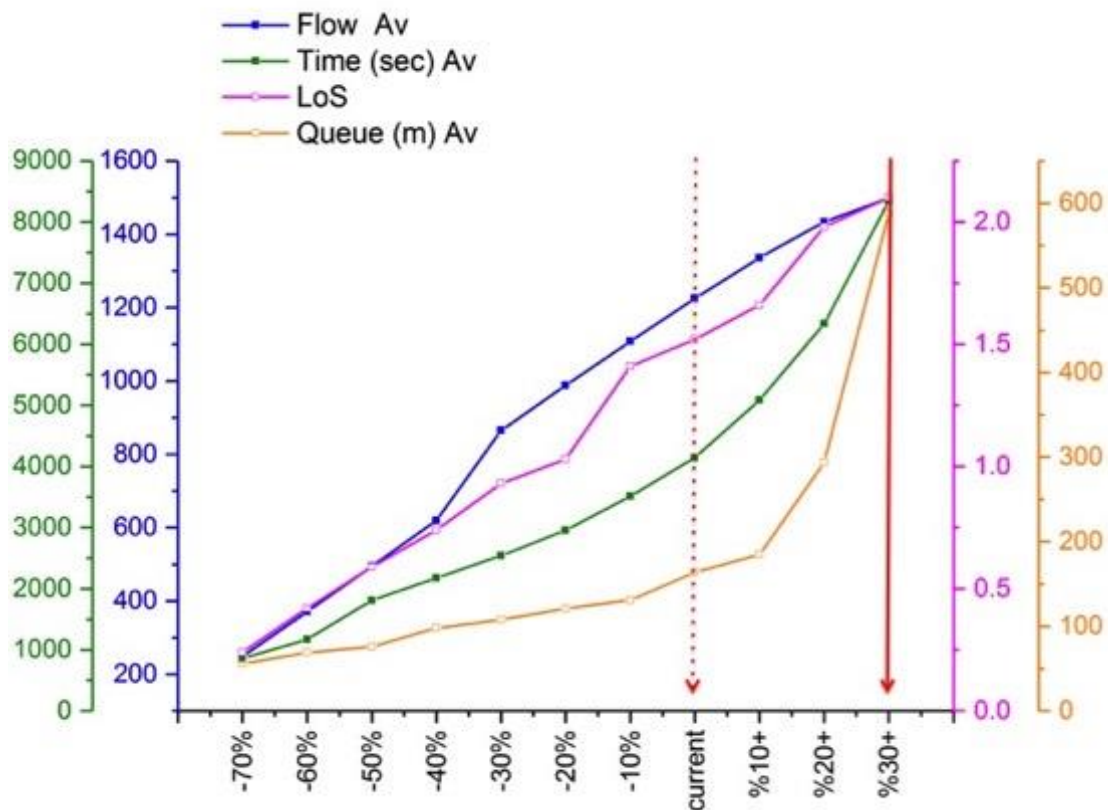


Figure 6.15 Composite OPCs for Riyadh current situation

Equally, it shows that in all the curves there is a critical point where the most rapid changes in the indicators occur. In addition, the OPCs show that the existing network of

Riyadh is already almost overloaded, and becomes completely saturated when traffic volume increases by 30%. This is forecasted to happen in four years' time. Importantly, however, is that in all the curves there is a critical region where the most rapid changes in the indicators occur.

This is vital information in the context of large-scale infrastructural improvements and policy interventions. Understanding how transport network performance varies under different traffic conditions is an essential factor in evaluating the condition of network and in formulating further improvement potentials. The OPCs show that the existing network of Riyadh is already in a critical state with only small further increases required to worsen the current situation dramatically in some cases.

In summary, this chapter has detailed how a set of OPC curves was derived, then presents the OPC curves themselves. With the network thus characterised, it becomes possible to scrutinise the expected and actual outcomes to be derived from the range of future scenarios as identified by key Riyadh transport stakeholders. This chapter has shown how Riyadh City Core responds to different traffic levels based on a range of different indicators: Level of Service (LoS), traffic flow, travel time and queue length. The next Chapter will use these OPCs to study the full impact of defined future scenarios

CHAPTER 7 Studying the impact of Riyadh transport future
scenarios

7.1 Introduction

This chapter investigates whether expectations around a number of different transport scenarios in Riyadh are justified. To achieve this, the research will explore the scenarios identified in Chapter 4. From the qualitative analysis, semi-structured interviews extracted a number of scenarios for the future of Riyadh's transport from key stakeholders/decision makers. All of these are designed to deal with the pressing problems outlined in Chapters 2 and 3, including congestion, public transport and the overlap between land use and transport. The key reason why there is a debate around the impact of different scenarios is policy transfer, a theme underlying all of this thesis and discussed in detail in Chapter 3.

To achieve the high-level research objective of **investigating the performance of future transport scenarios in Riyadh**, the research has created and calibrated a Strategic Microsimulation Model (SMM) of Riyadh's city core. This novel tool lies at the core of the analysis. It helps the research to examine the extracted scenarios in a highly structured way. The model extracts four network performance indicators:

1. Level of Service (LoS)
2. Queue length
3. Traffic flow
4. Journey time

The development of the SMM, and the derivation of the four indicators above, is fully described in Chapter 5. Chapter 6 then proceeds to iterate the model many hundreds of times across a wide range of traffic volumes, from freely flowing to complete saturation, to fully characterise network performance in terms of level of service, queue lengths, traffic flow and journey time. Performance across these four indicators is combined to create a composite Overall Performance Curve (OPC). Any future scenario will lie somewhere on these composite curves.

The extent to which the scenarios identified from the stakeholder interviews will lead to the expected effects can now directly tested. This involves adding/removing traffic volumes from the current network according to scenario expectations and using the composite OPC curves to establish the validity of these expectations with reference both to international best practice and policy transfer theory.

Reflecting on the overall thesis structure set out in Chapter 1, it can be seen that this chapter integrates the qualitative analyses conducted in Chapters 2,3 and 4 and the quantitative analysis undertaken in Chapters 5 and 6. Figure 7.1 serves as a reminder of the overall thesis structure and shows how this chapter integrates the qualitative and quantitative branches of the work.

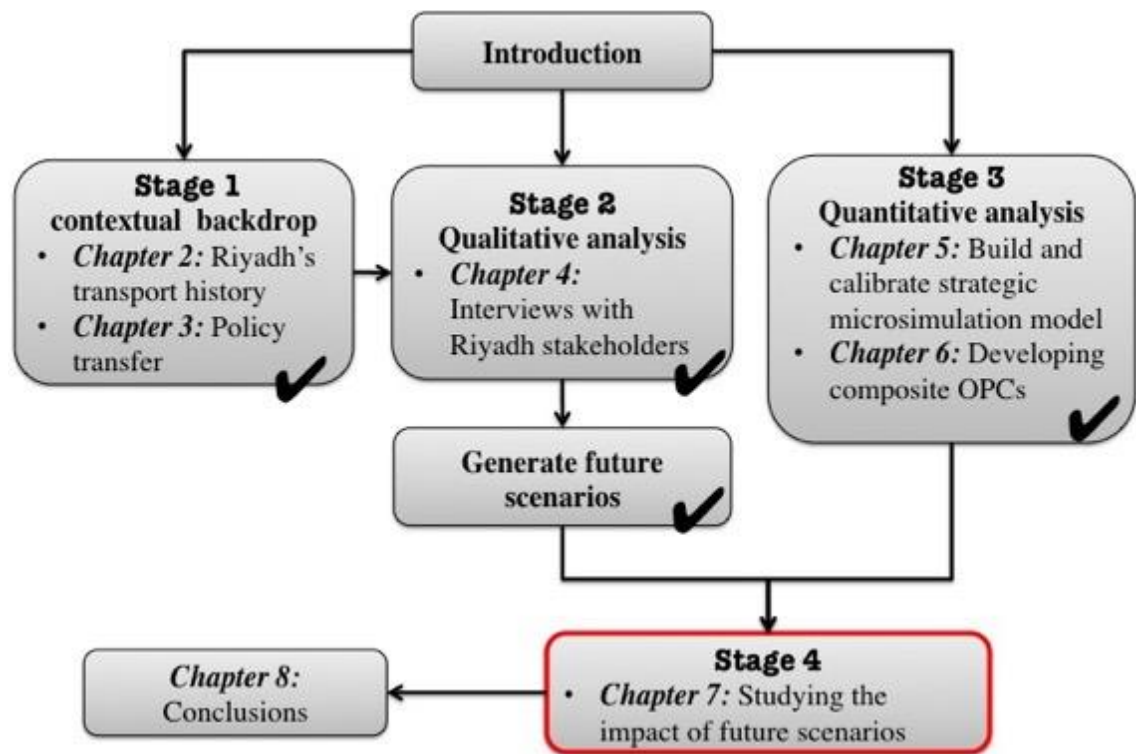


Figure 7.1 The graphical structure of the thesis and this chapter stage (Original: Author)

This chapter describe how analysing Riyadh's future transport scenarios combines with the SMM and the resulting OPC curves to answer the following research questions:

Research Question 15: To what extent can the extracted future strategies address Riyadh's traffic problems, and can these strategies succeed when combined or separate?

Research Question 16: To what extent are policy transfer issues manifest in the SMM results, and do they challenge existing assumptions?

The following sections cover the methodology used to address these research questions and the results obtained.

7.2 Methods

Here, the research undertakes to put actual numerical estimates onto the policy predictions and scenarios generated in Chapter 4. These estimates derive from the international best practice to which a lot of Saudi Arabian transport policy refers (as described in Chapter 3). The following policy transfer aspects will be considered:

Parameter 1: Policy transfer

Policy transfer (as fully described in Chapter 3) is defined as a best practice for resolving/addressing specific issues within a city/country which is a worthy model for others to adopt (Peck, J. 2011).

Parameter 2: Policy implementation

Policy implementation is related to policy transfer. It refers to the way a particular policy is implemented after it has been transferred from elsewhere.

Both of these parameters have the potential to modify the estimates taken from the Riyadh stakeholder interviews and international best practice, and will be scrutinised throughout the process. They lead to three hypotheses:

- **Hypothesis 1: Policy transfer and policy implementation both succeed** This assumes that the highest rate of policy implementation within selected best practice cities will also apply to Riyadh.
- **Hypothesis 2: Policy transfer or policy implementation (one of these factors) fails** In other words, it is the 'mid-point' prediction. This hypothesis will, therefore, assume that the average rate of policy implementation within selected cities will also apply to Riyadh.
- **Hypothesis 3: Policy transfer and policy implementation both fail** This assumes that the lowest rate of policy implementation within selected best practice cities will also apply to Riyadh.

Many factors contribute to the success or failure of policy transfer. As discussed in Chapter 3, policy transfer and implementation is a complex process with many side effects that need multidisciplinary specialists (McCann et al., 2013). Despite this, and whatever the validity of these assumptions, any scenario in Riyadh's transport future will inevitably fall somewhere on the OPCs. In other words, all possible transport futures can be represented by changes in the O/D matrix underlying the SMM.

7.3 Future transport scenarios for Riyadh

As mentioned in Chapters 2, 3 and 4, Riyadh is in some ways fortunate. It now has the opportunity and financial resources to plan its transport networks afresh. Outside of its central areas, there is the further chance to reserve lands for major transport infrastructures. This enables the planning of high quality transport to sustain high levels of mobility for future generations. Good mobility is generally recognised as a key

feature of prosperous world-class cities (Banister, 2005). Easy access across the city is vital for economic growth and for sustaining acceptable standards of living. Riyadh is well placed to take advantage of this.

The particular conditions applying to the Riyadh environment are unique. There is a particular dominance of private motoring, an increasingly dispersed pattern of socio-economic activities, very low use of public transport and particular cultural and societal norms influencing the travel behaviour of women in Saudi society (see Chapter 2). Several of these characteristics do apply to other cities, but not all of them are seen in the same city, as they are in Riyadh.

It is not possible, or indeed desirable, to specify a single numerical estimate for the efficacy of any given transport scenario. Hence this research takes a broader view by adopting low, medium and high forecasts, and reflecting these forecasts of the issue of policy transfer to try to understand which estimate may be more or less likely. In addition, the research presents the available forecast data from Riyadh's authorities alongside data on international best practice. This offers a more critical appraisal of the solutions on offer and their potential efficacy in Riyadh.

The following sections set out four distinct Riyadh transport futures. These represent a wide range of transport philosophies and solutions, all with a strong link to policy transfer within Riyadh's unique context.

7.3.1 Scenario 1: Do nothing

To help the process of critically appraising the future scenarios, a baseline is needed. This is embodied in Scenario 1, an approach of simply taking no action. In fact, the 'do nothing' option is quite common. Transport projects often go through a large cycle of procedures and debates via government and other multi-level decision-making processes (Banister, 2005). This, inevitably, slows down decision making. According to Kaysi (2010), the 'do nothing' option stems from two causes. The first is where the

government is not able to create or develop a particular transport intervention. Ability in this case refers to numerous factors, including political will, financial resources, demographics, etc. The second cause is that the government often wants to let the market deal with the problem (Kaysi, 2010). Thus, the market in one way or another will adopt the transport system which provides the necessary benefits (and returns on investment).

Alongside high-level government and policy issues, there are also more local physical constraints. These can also make the 'do nothing' option more likely. For example, in the smaller parts of Riyadh's old walled city, the design of the old market includes dense street patterns, limited parking spaces, pedestrian walkways etc., forcing people to leave their cars outside the walls even if they work or live inside them. In other words, people who travel within this part of old Riyadh must use alternative modes of transport. It is one good example of where 'doing nothing' really is the only viable option (ADA, 2015).

So doing nothing clearly *is* an option, and one which can be seen in other cities across the world. It is not the case in 'capital Riyadh' as planned by Doxiadis in 1972. It also runs counter to the prevailing modes of thought which continue to drive Riyadh's urban format, as encountered during the stakeholder interviews in Chapter 4. For these reasons, the city has become car-dominated (as explained in detail in Chapter 2), which itself now requires a solution. In other words, rather than 'doing nothing', the prevailing trend in Riyadh is very much to 'do something'. For present purposes, therefore, the 'do nothing' option might not be very realistic in isolation, but it is a vital analytical baseline. In this case it would mean, in theory, that Riyadh's transportation authorities took no actions for improving or changing the current network beyond that which currently exists.

In other words, there is no policy to be transferred or implemented. This, in turn, means Hypotheses 1, 2 and 3 will be as follows:

7.3.1.1 Hypotheses Nos. 1, 2 and 3: No policy transferred or implemented

For the purposes of developing the hypotheses, the research will assume the annual increase in car ownership will remain unchanged at 8% per annum (ADA, 2015), rising to 30% after four years. The OPC curves can show volumes in excess of 30%, but, as noted earlier in Chapter 6, beyond a 30% increase the network becomes fully saturated and gridlocked. To investigate the full impact of the ‘do nothing’ scenario, the composite OPC results show a 30% additional traffic volume on the network. Figure 7.2 shows Scenario 1 positioned on the composite OPC chart:

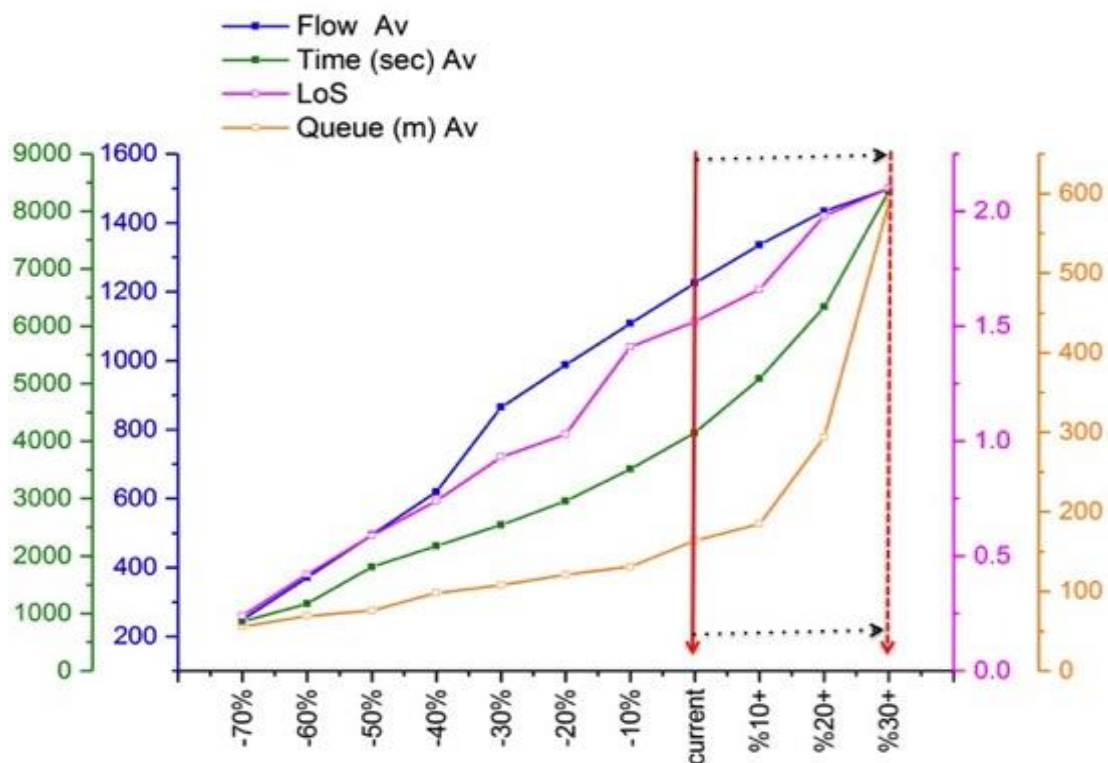


Figure 7.2 Scenario1 placed onto the composite OPC (Original: Author)

7.3.1.2 Results for Scenario 1

Looking more broadly, it can be seen how the ‘do nothing’ option moves the Riyadh City Core along some of the fastest changing parts of the indicator curves. In particular, queue lengths will increase dramatically and disproportionately. Table 7.1 below shows the Scenario 1 results:

Table 7.1 Results of Scenario 1

OPC	Current value	H1, 2 & 3*	% Increase in traffic volumes	Change in indicators
Queue length (m)	146	604	30%	+368%
Travel time (sec)	4144	8343		+201%
Traffic flow	1225	1498		+122%
LoS	F	F		F

* Hypotheses 1, 2 and 3 are assumed in this case to be identical

This scenario does not serve the transport network at all, indeed it will actively increase Riyadh's transport problems. As explained in Chapters 2, 3 and 4, Riyadh is currently close to this point, and further increases will accelerate problems drastically (they won't increase linearly). However, the composite OPC results can be summarised as follows:

- Mean queue length will increase from 146 metres to 604 metres, which is (368%) longer than current queue length
- Mean travel time will more than double from 69 minutes 4 seconds to 139 minutes and 3 seconds
- Mean traffic flow will, on average, increase from 1225 to 1498 vehicles (an increase of more than a fifth at 22 %)
- LoS will remain at F, but the volume-to-capacity ratio will increase from 1.65 v/c to 2.03 v/c. This means there is double the volume of traffic compared to the available capacity to carry it

Although doing nothing may be considered one option for forcing people to use different modes of transport such as public transport, cycling, or even walking, this research argues against going down this path. Significant urban expansion, demographic change, poor public transport provision (consisting mainly of jitneys) and other factors, such as the climatic and cultural aspects, work against modal shift.

As discussed in Chapters 2, 3 and 4, the Riyadh Metro is on the ground now, which to a large extent nullifies the ‘do nothing’ scenario. After all, something *is* being done. That said, the ‘do nothing’ scenario may apply to some smaller areas within old Riyadh, which are distinct from the city’s modern districts, but certainly not fit for the Saudi capital as a whole. It is important, therefore, that a large-scale ‘do nothing’ policy is not adopted. This is because of a poor prognosis of how metropolitan life in Riyadh would develop in the coming years if such a policy were to be implemented.

There are clear examples (including Portland, Stuttgart, Kuala Lumpur and Los Angeles) in many countries where a poor appreciation of the long-term effects of uncontrolled traffic demand have led to chronic and widespread congestion, severe conflicts of interest between different users and poor planning of relationships between land use and transportation (Banister, 2005). But, while offering limited practical benefit in Riyadh, Scenario 1 does serve as a useful counterpoint against which to compare a range of alternative ‘do something’ scenarios.

7.3.2 Scenario 2: Public transport

The public transport option was the key solution agreed on by all the participants in the interviews outlined in Chapter 4. Other leading global cities (such as London, Paris and New York) have taken this option, to varying degrees, a long time ago. This is a reflection of how those cities have developed, and several among them predate widespread car use. In Riyadh, this scenario is currently under construction. Transport officials here are placing high value on this scenario as a policy that will significantly improve the city’s current transportation problems (ADA, 2015).

This project is the focus of the Saudi government at all levels, with daily follow-up reports to the ministries Council (see Chapter 4). The project therefore has considerable support, and there is likely to be continued investment in its success. In fact, the Riyadh Metro is one of the largest transportation projects in the world at a cost of USD 22.5 billion (ADA, 2015), and it will serve the whole city across all destinations to enhance accessibility door-to-door for all travellers, which is at the core of the transport and land

use integration cycle shown in Figure 7.5. This integration is the milestone of a sustainable transport system that helps a city to deal with its transport problems in the long term (see Chapter 3).

In terms of the demographical and social aspects, the metro was designed to fit the Saudi people's particular cultural characteristics and to meet their needs. This, in turn, enhances the chances of policy transfer's success as mentioned in Chapter 3. Key to its success is the important matter of demonstrating that public transport in Riyadh can be attractive and well used. According to experience in other cities (e.g. Bruce, 2010; Ecola et al., 2009; Smith, 2016; Los Angeles Metropolitan Transportation Authority, 2016; Paris by train, 2016; McGuire, 2017; MTA, 2016; Cairo metro, 2017), there are marked differences in public transport ridership. Key data from the selected international examples is presented in Table 7.2.

Table 7.2 Summary of PT systems from selected cities worldwide (Original: Author)

City	Portland	Stuttgart	London	Kuala Lumpur	Paris	Cairo	Los Angeles	Dubai
Population (million)	0.6	0.6	8.6	1.6	2.2	9.5	9.6	2.9
Length (km)	47.4	112	407	50	214	65.5	158.5	74.6
Users (million/year)	86	303	Over 1000	-	Over 2000	Over 1200	Over 1200	120
Ridership	27%	29%	43%	16%	39%	27%	10.2%	7.4 %

PT ridership worldwide varies between 7.4% and 43% of a city's total population. All these experiences are currently missing from Riyadh. The Riyadh Metro is the first such mass transit scheme in Saudi Arabia, and one of very few across the whole of the Middle East. The project will provide a valuable learning platform for those responsible for decisions about subsequent public transport developments.

As shown in the table above, this research only comparing Riyadh to cities with an existing metro system worldwide, taking into account the cities which have been mentioned by the participants in Chapter 4. Although the research seeks to compare

Riyadh with cities that have similar conditions in terms of demographical, climatic or cultural/religious contexts, but unfortunately, there is no existing system in MENA, except Cairo and Dubai.

Riyadh is very different, both demographically and culturally, from many of the cities shown in Table 7.2. It's interesting to note, that table 7.2 also supports the expectations of ADA in terms of the metro ridership. Cairo is also the capital city with 9.5 million populations and it shares Riyadh in many features such as; Islam religion, climatic, and many cultural aspects, taking in mind that Metro Cairo was established in 1970.

In contrast, Dubai has a similar metro system and, at face value, might provide valuable lessons for the Saudi capital, not least because ridership in Dubai falls a long way short of the ADA's predicted 20%. So it's important to explore this in a little more detail.

7.3.2.1 Riyadh metro versus Dubai metro

As noted in Table 7.2, not only is ridership on the Dubai Metro somewhat lower than the ADA's predictions for its system, it also has the lowest PT ridership of all the comparison cities. Does this mean current estimates are too optimistic, or are there factors which sharply differentiate Riyadh from Dubai, despite their geographical proximity? Since it is a nearby example of Middle Eastern public transport, it's useful to highlight the factors affecting ridership on Dubai's metro system. These are listed in the table below and include having a much smaller population, vastly different demographics, and in the case of Dubai, a much smaller network.

Table 7.3 Riyadh and Dubai metros: statistics, facts and its reflection on ridership (Sources: ADA, WAM, author)

Factor	Dubai	Riyadh	Reflection on ridership
Demographical data			
City population (millions)	2.5	8	The population reflects the scale of service to be implemented to connect the whole city, the size of the project, and its components. According to Litman (2015), transit travel demand increases with population growth. For example, between

			2004 and 2012 the US population grew 6%, motor vehicle travel declined 1% and transit ridership increased 14%.
Per capita income in USD (thousands)	46.47	20.8	Income level is the main player in motivating low-income people to use the metro and avoid the additional costs to their trip. Most transit trips are made by lower-income households, who represent 63% of riders in small transit systems, 51% in medium-sized transit systems and 41% of riders in large transit systems (Litman, 2015).
Average age of population	32	18	According to Litman (2015), a significant number of students depend on public transit to commute to schools and colleges
male/femal%	77/23%	52/48%	Attractive to use by women
Women driving	Yes	No (currently)	
Metro data			
Length km	74.6	171.21	The length reflects city coverage and accessibility
Cost USD billion	4.5	22.5	The cost reflects the quality of the metro system
Cost per km (USD million)	131 m/km	60 m/km	
Carrying capacity	6935	+18000	The capacity, lanes and stations reflect the quality level of service provided
Lanes	2	6 + 3 (BRT) lines	
Stations	47	85 + 34 (proposed)	
Daily ridership	329,365	1.6 million	

As seen in the table above, Riyadh's metro is obviously much larger than Dubai's in terms of its network specifications. Riyadh's metro is three times the size of its Dubai counterpart – it's also 140% longer and five times more expensive. Moreover, the Riyadh Metro consists of six main lines plus three BRT ones, compared with two lanes on the Dubai version. This research doesn't cover engineering features for all metro characteristics (either in Riyadh or Dubai), but all these figures give a clear indication that the Riyadh Metro project is much larger than Dubai's.

On the other hand, there are also huge differences in the demographical aspects of both states, including population pyramids showing about 77% male against 23% female in Dubai, and 52% male against 48% female in Saudi Arabia, meaning large parts of the population will not be able to drive legally in Riyadh currently, increasing the chances of metro ridership in the short term. Additionally, the average age in Riyadh is 18 (undergraduate age), which will attract students to use the Riyadh Metro

Moreover, per capita income is significantly higher in Dubai, at USD 46.47 thousand compared with USD 20.8 thousand in Riyadh. This encourages lower-income people to use the metro to avoid the extra cost of running their own cars, as mentioned above. Most transit trips are made by lower-income households (Litman, 2015).

In conclusion, these factors show that Riyadh and Dubai have marked differences in terms of demographical figures and metro statistics. This, in turn, gives the Riyadh Metro valid evidence that it will achieve a higher ridership forecast than the Dubai Metro.

Despite the very evident complexity inherent in debates about modal change, one can still apply the same three policy transfer hypotheses and examine their effects using the composite OPC curves.

7.3.2.2 Hypothesis 1: Policy transfer and implementation succeed

This hypothesis is the most optimistic. It suggests that the public transport option will be in the best condition in terms of policy transfer and implementation. Hypothesis 1 suggests that Scenario 1 will remove 43% of traffic volume within the study area if both policy transfer and implementation succeed. This follows the example of London, the highest percentage of the selected cities, and makes the highly optimistic assumption that every person riding the metro equates to one less car journey on the network.

Although the Riyadh Metro is a new project which plans to become operational in 2020, the age of such public transport projects is a key factor in encouraging people to use them. For example, cities that have achieved high ridership levels, including London and Paris, have public transport systems dating back to the nineteenth century which have become integral parts of the fabric of these cities (as explained in Chapters 2,3 and 4). In Riyadh, the big challenge is how to encourage people to switch to use the brand new Riyadh Metro instead of continuing to use their cars. If the timescales for people switching to public transport are greater than the forecast increase in road traffic, considerably less optimistic predictions may be needed.

7.3.2.3 Hypothesis 2: Policy transfer or implementation fails

This hypothesis suggests that public transport ridership is lower than expected in terms of policy transfer issues (for the manifold issues described in Chapter 3), or it fails in terms of its implementation for a range of other reasons. Assuming the Riyadh Metro is 'engineered' approximately on schedule and to budget, the remaining barriers will be 'soft' ones. Will people be willing to leave their (air conditioned) cars to ride the metro? Will the provision of luxury features be enough? How attractive will the travel facilities be to women, and will the system really meet everyone's expectations in terms of privacy and modesty? Hypothesis 2, therefore, suggests that the public transport scenario will remove a smaller volume of 25.1% of traffic from the road network.

7.3.2.4 Hypothesis 3: Policy transfer and implementation both fail

Hypothesis 3 is the most pessimistic one. It suggests that the public transport option will be in the worst condition in terms of policy transfer and implementation. Hypothesis 3 suggests that the public transport scenario will only remove 7.2 % (or less) of traffic volume within the study area if policy transfer and implementation fail. As discussed above, this figure is drawn from the example of Dubai.

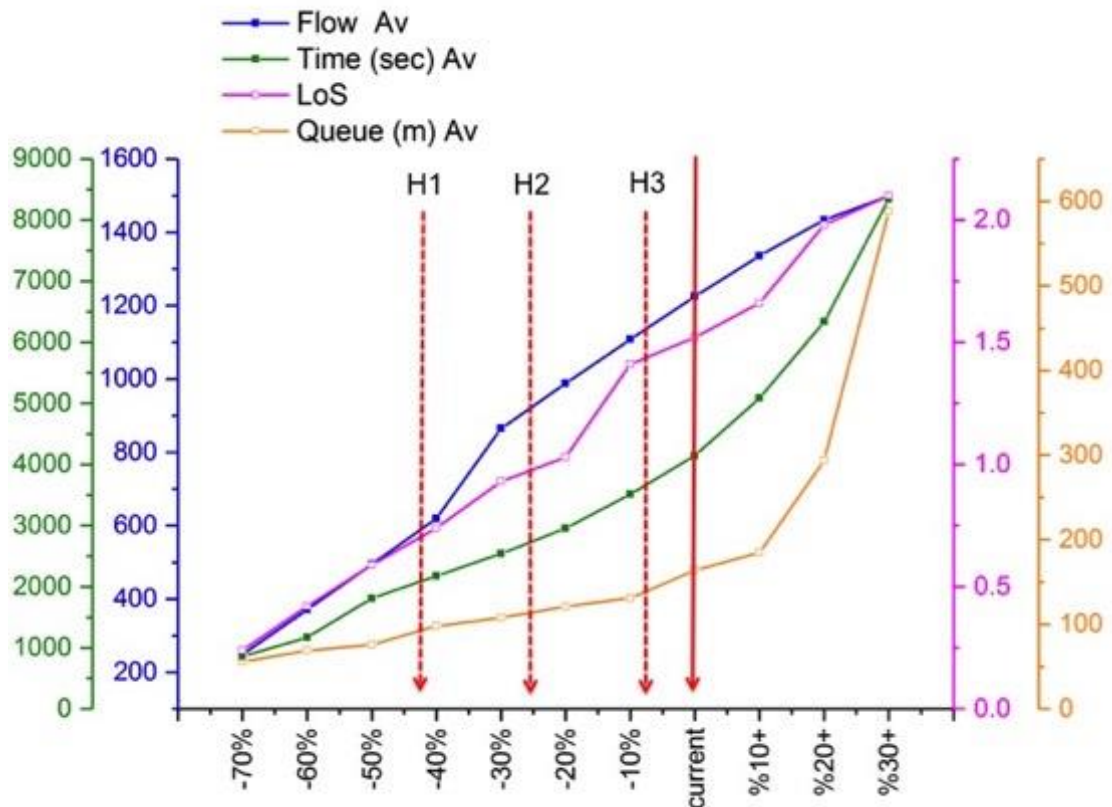


Figure 7.3 Scenario 2 positioned onto the composite OPC chart Original: Author)

7.3.2.5 Results for Scenario 2

Hypothesis 1 (43% PT ridership) will contribute to solving transportation problems in Riyadh as follows:

- Mean queue length will shorten by 54 metres from 146 metres to 92 metres

- Mean journey time will fall by around half from 69 minutes and 4 seconds to 35 minutes and 17 seconds
- Mean car flow will reduce by about 50% from 1225 vehicles to be 614
- A significant improvement on LoS, which was 1.56 v/c F grade, to .68 v/c at B grade

Hypothesis 2 (25.1% PT ridership) results show a slight improvement as follows:

- Mean queue length will drop 42 metres from 146 metres to 104 metres
- Mean journey time will be 42 minutes and 42 seconds compared with the current 69 minutes and 4 seconds
- Mean vehicle flow will reduce by about 40% from 1225 vehicles to 871
- LoS will improve to Grade C (compared with Grade F, the current situation)

Hypothesis 3 (7.2% PT ridership) noted no significant changes on the network, as follows:

- Mean queue length reduced by 15 metres from 146 to 131
- Mean journey time will be 9 minutes and 34 seconds shorter, dropping from 69 minutes 4 seconds to 60 minutes 30 seconds
- Mean car flow will improve by about 9% from 1225 to 1117
- LoS stays the same at Grade F

Table 7.4 shows the values of all the network performance indicators for all scenarios and hypotheses:

Table 7.4 Results of Scenario 2

OPC	Current value	Hypothesis 1 43% ridership	Hypothesis 2 25.1% ridership	Hypothesis 3 7.2% ridership	Riyadh authorities' forecast (20% ridership)
Queue length (m)	146	92	104	131	111
Travel time (sec)	4144	2127	2562	3630	2589
Traffic flow	1225	614	871	1117	937
LoS grade	F	B	C	F	C

Table (7.4) shows that the public transport scenario has great potential, but is also heavily influenced by policy transfer issues. The key knowledge deficits at present concern the extent to which Saudis will use modern public transport and the range of factors attracting ridership. This is because Riyadh has a unique cultural and demographical situation, as described at length in Chapters 2, 3, and 4.

7.3.2.6 Riyadh's authorities' forecast

The ADA predicts that the new Riyadh metro will remove 20% of the traffic volume from the city core. This is in line with Hypothesis 2, and anticipates a similar PT ridership to those found in Portland and Stuttgart. In Riyadh, the metro project is seen as a unique opportunity to introduce a modern public transport system to a developed urban area that is, by any measure, currently without any recognisable public transport (ADA, 2015). But it is a major challenge to persuade car users to transfer to public transport, since people will only do this when the alternative offered is as comfortable and quick as their cars, and when it is generally perceived as attractive and convenient for a whole journey.

The challenge is to change Saudis' attitude towards using public transport as a daily experience. This will not be achieved in a short period (see Chapters 2, 3 and 4), because changing peoples' attitudes and their travel behaviour is a gradual process as users become both comfortable with the new services and confident about its consistent reliability (ADA, 2015). The ADA expects that the Riyadh Metro will contribute to the prosperity of the transport system in the city in the following ways:

- Cutting more than 2.2 million daily private car trips, saving 1.46 billion SAR
- Cutting more than 30km of road trips per day, saving 4.5 billion SAR of journey time per year
- Saving 1.2 billion SAR in negative impacts of congestion annually
- Cutting more than 800,000 hours on the roads every day, in turn saving 693 million SAR annually in additional costs from air pollution
- Reducing fuel consumption by 620 million litres per year
- Preventing more than 13,500 traffic accidents per year, saving 400 million SAR of accidents annually

According to the ADA (2015), the year 2020 was selected as the year when the metro, BRT and bus systems would be running, and the ramp-up period would be finished. Under these conditions, the projected ridership for the Riyadh Metro was more than 1.6 million passengers daily (of Riyadh's total population of eight million), travelling with public transport services on all lines (including BRT), which is how the projected 20% PT ridership is calculated.

According to this research, the ADA's predictions seem reasonable. They represent a mid-point estimate: lower PT ridership than Paris or London, which both have well-established metro systems, but higher than Dubai's, which is a smaller and more distinct example, despite being relatively nearby. This offers the research a degree of face validity.

The ADA's PT ridership estimates are based on extensive and costly analysis (e.g. financial, boarding/alighting and operational modelling), and it is reassuring that this research independently agrees with broadly similar estimates. What this research identifies, however, are some potential risks. From the policy transfer literature (notably demographical aspects, topology and culture), we know that project size and ambition is no guarantee of success. Indeed, in some cases, quite the reverse is true. Just because a policy intervention has proven successful elsewhere does not mean it will succeed in a different context. This thesis identified in Chapters 2 and 3 Riyadh's numerous unique features, which could give rise to less favourable outcomes than expected, such as the Doxiadis master plan and its deep-rooted effects on Riyadh's urban form, particularly on car ownership.

Most critical, however, is the research showing via the OPC curves that relatively small changes in policy transfer and implementation could have a significant impact on key network performance indicators. For example, if PT ridership reaches 18% instead of the forecast 20% - a mere 2% shortfall - queue lengths will be 116 metres instead of 111 metres, LoS will remain at C with an increase from 0.81 to 0.89 v/c, and average journey times will be 49 minutes and 6 seconds rather than 43 minutes and 9 seconds.

A 5% shortfall in PT ridership diminishes the project's success even further (with LoS now D and 0.97 v/c, journey times 54 minutes and 17 seconds, with an average queue length of 124 metres). The OPC curves show that the network is sensitive to small changes in traffic volumes, and these small changes fall well within the scope of policy transfer and implementation issues.

7.3.3 Scenario 3: Private car reduction strategy

This policy is the combination of several techniques aimed at reducing private car use across the city. PT is, of course, one of those techniques, but has been considered separately above. This section explores other traffic reduction strategies.

According to the Victoria Transport Policy Institute (2017), there are several congestion reduction strategies which have been implemented in capital cities to reduce private car use. These strategies include improving transport options (as per the PT option above), congestion charging, parking fees, fuel taxation, distance-based insurance and registration fees and park & ride schemes, among other ideas. These strategies aim to encourage people to use alternative means of transportation rather than their own cars because of the additional costs to their journey (Litman, 2017). Currently, Riyadh does not use any of these strategies which, according to the underpinning research (e.g. Alfoazn, 2011; Al-Dubikhi, 2007; Al-Hathloul, 2002; MOT, 2016) contributes to the city's high levels of car ownership (see Chapter 2).

For the present purposes, these strategies are treated separately from the public transport system (Scenario 2), but clearly they will be more effective if the public transport system is working well. In theory, Private Car Reduction (PCR) strategies encourage people to use different methods of transport or even to reconsider the need to travel in the first place. According to research in this area (Bruce, 2010; Ecola et al., 2009; Smith, 2016; Los Angeles Metropolitan Transportation Authority, 2016; Paris by train, 2016; McGuire, 2017; MTA, 2016), these strategies have reduced vehicle flow rates. Table (7.5) shows the proportion of traffic removed from the network as a result of PCR policies within selected cities.

Table 7.5 Proportion of traffic removed from the road network as a result of PCR policies within selected cities
(Original: Author)

City	Proportion
New York	27.8
Chicago	13.7
San Francisco	9.3
Seattle	6.3
Portland	11.9
Los Angeles	4.6
Miami	4.4

As noted in the table above, large capital cities use PCR policies to encourage the use of different transport methods rather than the private car. In New York, for example, the proportion of cars removed from the network as a direct result of these policies is 27.8% (Bruce, 2010). In Miami, on the other hand, that figure is only 4.4% (Ecola et al., 2009). Both cities have public transport services, but the difference in PT ridership is due to New York's stricter regulations limiting private cars with measures such as restricted or expensive parking and further costs for private car use including road tax, licence limitations, etc.

Transport planners and economists have accepted that road pricing is a potentially effective measure for reducing traffic congestion (Anas & Lindsey, 2011; King et al., 2007). This has been used in many cities worldwide including London, Paris and New York, among others. Many researchers discuss road pricing schemes and their political, economic and social impacts, including Arnott & Small (1994) and Hensher (2012). This on its own is a complex, much-studied topic that need not be reviewed again in detail here. Suffice it to say that it has proven highly effective in many locations. In London, for example, the introduction of a congestion charging scheme in 2003 reduced traffic by 15% within the charging zone, while bringing a number of other favourable impacts, for example on air quality (Transport for London, 2017).

In many developing countries, a form of 'de facto' PCR policy exists by simple virtue of shortages in the supply of transport. This makes certain areas of developing countries and large parts of some big cities physically inaccessible. This form of 'uncontrolled' PCR often leads to unexpected side effects, such as the development of 'para transit' operators such as jitneys. These are a means of unregulated transport run by informal operators which, according to Cervero (1998), serve as gap fillers. In West Africa, for example, jitney operators use mainly motorcycles and small old vehicles for illegal urban transport. Jitney operators are usually non-corporate and function outside the official taxation and insurance systems.

Riyadh has a similar sector in the form of informal bus services (or jitneys). These are managed by the drivers themselves, with no formal regulation such as designated stops/stations, routes or timing. Unsurprisingly, these relatively unattractive PT options further encourage people to travel by private car where possible (as fully described in Chapter 2). Despite this, however, many countries facing transport problems caused by shortages in vehicle supply tolerate informal transport operators because they are deemed necessary for certain services.

To study the impact of the PCR scenario on Riyadh, this research puts forward three hypotheses:

7.3.3.1 Hypothesis 1: Policy transfer and implementation both succeed

This hypothesis is the most optimistic one. It assumes that the private car use reduction policy has been transferred and implemented successfully and will reduce traffic volume by 27.8%, following the highest figure (New York's) from among the international cases.

The results of this hypothesis on composite OPCs are shown in Figure 7.4, and will be discussed in greater detail in the results section.

7.3.3.2 Hypothesis 2: Either policy transfer or implementation fails

This hypothesis suggests that the private car reduction policy is below expectations in terms of policy transfer issues (such as those described in Chapter 3), or it has failed in terms of its implementation for some reason. Thus, Hypothesis 2 suggests that Scenario 3 will remove 16.1% (the mid-point of international cases) of traffic volume within the study area.

As mentioned previously, the biggest challenge is to persuade drivers to abandon their cars even if such policies are in place (which often add extra costs to a journey). Will Saudis consider this cost or not?

7.3.3.3 Hypothesis 3: Policy transfer and implementation both fail

As mentioned in Chapter 3, Saudi Arabia is a wealthy country, therefore people may be willing to pay more for their trips. For example, rich people may not mind paying for road pricing (or other charges), as long as they have the opportunity to drive their own cars in the city. According to this assumption, the research assumes that this policy will not significantly improve the current network (indeed, it may fail).

This hypothesis is very pessimistic, meaning that the PCR option will be in the worst condition in terms of policy transfer and implementation. Hypothesis 3 suggests that Scenario 3 will remove 4.4% (following Miami, which had the lowest figure among the international cases) of traffic volume from the study area if this policy transfer and implementation both fail. Figure 7.4 below shows the full impact of Scenario 3 on composite OPCs.

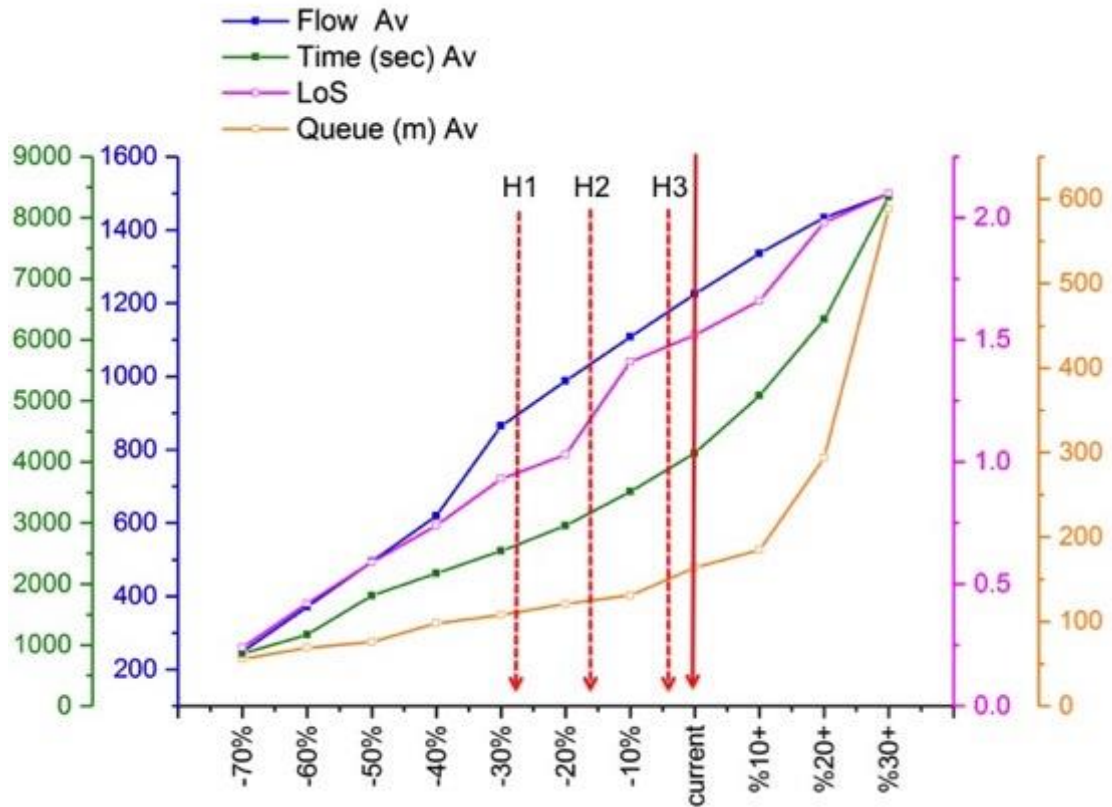


Figure 7.4 Scenario 3 positions on the OPCs (Original: Author)

7.3.3.4 Results for Scenario 3

Scenario 3 results suggest that this policy will improve the current network by removing 27.8% of traffic volume if it is implemented and transferred successfully, following the best international case (New York), as detailed below:

- Queue length will shorten by 34 metres from 146 metres to 112 metres
- Average journey times will drop by 16 minutes and 38 seconds from 69 minutes and 4 seconds to 52 minutes and 42 seconds
- Vehicle flow will fall from 146 to 112 which is 27% of the current situation
- LoS 0.72 v/c at B grade

Hypothesis 2 results show a slight improvement on the current network as follows:

- Queue length will be reduced by 17 metres from 146 metres to 129 metres
- Journey time will drop to 60 minutes and 30 seconds from 69 minutes and 4 seconds
- Vehicle flow will be reduced by 17% of the current situation from 1225 to be 1006 vehicles.
- LoS remains at D grade

Hypothesis 3 noted no real changes on the network, as follows:

- Queue length will drop by 11 metres from 146 metres to 135 metres
- Journey time will fall to 65 minutes from 69 minutes and 4 seconds, saving 4 minutes and 4 seconds
- Vehicle flow will be reduced by about 4% from 1225 to 1118
- LoS remains the same at Grade F

All results for Scenario 3 hypotheses are shown in detail in Table 7.6 below:

Table 7.6 Results of Scenario 2

OPC	Current value	Hypothesis1 removing 27.8% traffic	Hypothesis2 removing 16.1% traffic	Hypothesis3 removing 4.4% traffic	Riyadh's authorities' forecast
Queue length (m)	146	112	129	135	n/a
Travel time (sec)	4144	3162	3630	3904	n/a
Car flow	1225	884	1006	1118	n/a
LoS Grade	F	B	D	F	n/a

7.3.3.5 Riyadh's authorities' forecast

On the ground, Riyadh Municipality, in cooperation with the ADA, will start operating parking charges in the centre of Riyadh. This scheme will be activated after the launch of the city's public transport system. Moreover, officials in the Saudi capital also support this claim, as described in the interviews in Chapter 4. According to the ADA, once the metro system is operational, the Municipality of Riyadh will develop parking payment and similar schemes. The Ministry of Municipal and Rural Affairs has stated that the road and service pricing plan will be announced after launching the metro, and a specialist company will manage and operate it.

However, to estimate the impact of this policy, further information is needed about these projects, including type of scheme, applicable areas, price and targeted zones. Unfortunately, at the time of writing this research, there is currently no data about what schemes will be used in Riyadh specifically.

7.3.4 Scenario 4: Replan land use

As mentioned in Chapters 1, 2 and 3, integrating of land use with transport systems leads to a city having a sustainable urban transport network. According to Wegner (2009), this integration can only be achieved with effective land use, since half of this integration cycle (reproduced below in Figure 7.5), and the obvious question for all road users is: Why is there congestion in this area specifically instead of other areas? In addition, having workplaces in the central areas means employees based in the suburbs must travel daily to the city centre, increasing pressure on the network, especially if there is no public transport system, as is the case in Riyadh. According to Robert (1991), combined land use is an initiative which can make future suburban workplaces more in line with high levels of mobility.

In Riyadh, the rate of growth has been very high. And, as mentioned in Chapter 2, Riyadh's rapid urban expansion has exacerbated the transport problems mentioned earlier in this research. According to the ADA (2015), the annual urban growth rate in Riyadh is 7%, which is much higher than that of developed cities (Duranton et al., 2012). Ideally, a combination of several sets of trip destinations can be identified based on a strong and growing demand in a specific area along the line of the route. This achieves maximum effectiveness (Duranton et al., 2012). Additional guidance on route location can be sought by considering international practices in other urban areas. Riyadh can still learn from other cities' successes as it builds a new public transport system. According to the interviews with Riyadh transport stakeholders, this research assumes that replanning land use will contribute effectively to reducing current traffic volumes in the central area, since Riyadh is still a growing city.

To study the impact of this scenario on the transport network in Riyadh, the following section presents the hypotheses related to this scenario. There are three hypotheses, as follows:

7.3.4.1 Hypothesis 1: Policy transfer and implementation both succeed

This assumes that Riyadh will successfully transfer and implement the concept of smart growth and land use, leading to integration with transport (as shown in Figure 7.5 above). This, in turn, will reduce the traffic volume within the study area in light of its rapid growth. Hypothesis 1 suggests that Scenario 4 will remove 7% of traffic volume (according to Riyadh's annual growth). In fact, the key point in this hypothesis is whether Riyadh has already developed MEDSTAR in accordance with its transport needs. Has the new transportation network plan including the metro project been developed to integrate land use and urban transport?

This hypothesis suggests that new suburban projects support the idea of sustainable transport, and it will mean people do not need to travel to or across the city centre.

7.3.4.2 Hypothesis 2: Either policy transfer or implementation fail

This suggests that the policy of replanning land use policy is below expectations in terms of policy transfer issues (including those described in Chapter 3), or its implementation has failed for some reason. As mentioned in Chapter 3, the current city plan encourages the use of private cars as the main mode of transport. Will a focus on suburbs be a new philosophy aimed at changing travel behaviour?

Thus, Hypothesis 2 suggests that Scenario 4 will remove about 4.5% of traffic volume within the study area (this is the midway point between highest and lowest figures in developed cities).

7.3.4.3 Hypothesis 3: Policy transfer and implementation both fail

This hypothesis is very pessimistic and means that the land use replanning policy will be in the worst condition in terms of both policy transfer and implementation. It assumes that Riyadh will not successfully integrate land use and urban transport, and that rapid urban growth will not take transportation needs into account, thus none of the urban development projects will serve the transport network, even if a public transport system is in place, as per the Doxiadis master plan of 1972 (see Chapter 3).

Hypothesis 3 suggests that Scenario 4 will remove less than 2% of traffic volume within study area (the lowest rate of international cases) if policy transfer and implementation both fail.

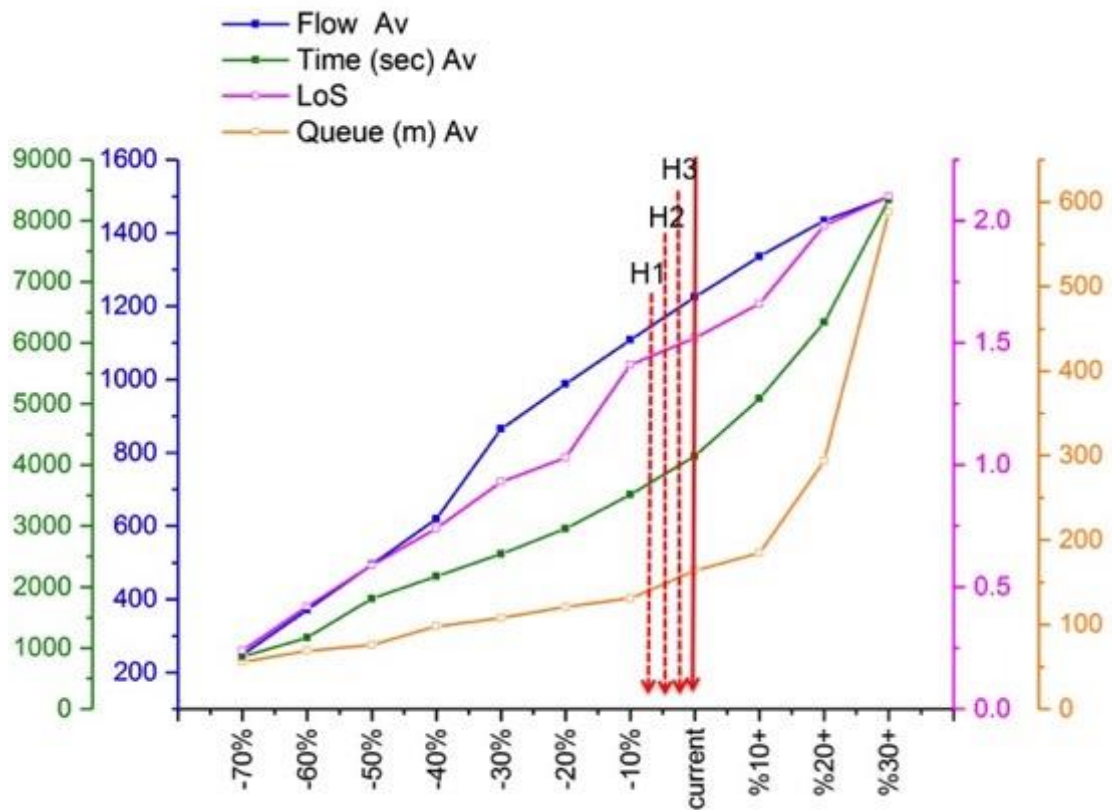


Figure 7.6 Scenario 4 positions placed onto the OPC (Original: Author)

7.3.4.4 Results for Scenario 3

In this scenario, composite OPCs results noted that:

Hypothesis 1:

- Queue length will shorten by 7 metres from 146 metres to 139 metres
- Travel time will fall by 5 minutes and 7 seconds from the current situation of 69 minutes and 4 seconds to 64 minutes and 11 seconds
- Traffic flow reduces from 1225 to 1092 vehicles
- LoS remains at Grade F

Hypotheses 2 and 3 are likely to be on the same position on composite OPCs, with less than 1% change across all indicators. The results for the Scenario 3 hypotheses are shown in detail below in Table 7.6:

Table 7.7 Results of Scenario 4

OPC	Current value	Hypothesis1 removing 7% traffic	Hypothesis2 removing 4.5% traffic	Hypothesis3 removing 2% traffic	Riyadh's authorities' forecast
Queue length (m)	146	139	142	144	n/a
Travel time (sec)	4144	3851	3984	4021	n/a
Traffic flow	1225	1092	1124	1206	n/a
LoS grade	F	F	F	F	n/a

As noted in the table above, Hypothesis 1 will improve the transport network more significantly than Hypotheses 2 and 3 (which are at the same position on composite OPCs), even though LoS stays the same at Grade F. Although this improvement is not huge, it can be enough to help solve transport problems if the city has also adopted a policy of integrating transport and plan use.

7.3.4.5 Riyadh's authorities' forecast

A key component of the ADA's growth strategy is the creation of five or more sub-centres (see Chapter 3) within the urban area to reduce dependence on central area for jobs and shopping. Together, these sub-centres will serve perhaps one million people, or 20% of the expected growth in population.

The major new towns being planned with a population of one million people will be semi-autonomous, and their impact on the highway network cannot currently be accounted for, since there is no accepted trip matrix for 2020 that can be used to assign traffic (ADA, 2015). The estimates of future traffic conditions therefore exclude the

traffic generated by these new towns. The establishment of sub-centres and Riyadh's future plans for its suburbs (ADA, 2015) contribute positively to solving transport problems. Nevertheless, the Riyadh Metro project will contribute to the replanning of land-use by connecting the city and facilitating mobility.

As mentioned earlier, when developing cities such as Riyadh there is the chance to replan and develop land use to a far greater extent than in other developed cities including London, Paris, New York, etc. Moreover, the Saudi economic situation and the decision-making process contribute effectively to replanning land use, giving Riyadh the perfect opportunity to develop and create more sub-centres as described earlier (see Chapter 2.3.4).

Based on Riyadh's urban form trends mentioned above, this research relies heavily on this scenario in parallel with others to integrate land use and urban transport integration. And it supports Hypothesis 1, which will remove 7% of current traffic volume. It also argues that replanning land use would increase the chances of reducing traffic volume on the network much more than current assumptions, due to existing projects (see Chapter 2.3). As mentioned earlier, Riyadh is still under construction and has vast areas with huge urban growth potential, which will contribute significantly to better land use and smart growth planning.

7.4 Discussion

As mentioned in Chapter 4, Riyadh is unique in terms of its cultural and demographic aspects and its financial situation. Almost all Saudis commute by private car, and the highway networks have become steadily more congested in recent years. Lessons learned from international best practice suggest that the policy transfer framework (see Table 3.1) and its implementation are key factors in the success of any of these scenarios in Riyadh's transport future. The ADA has undertaken various studies of the city's development and its needs through the Metropolitan Development Strategy for Arriyadh (MEDSTAR) scheme.

MEDSTAR addresses strategic planning for Riyadh, and it has recognised that the success of the expected planning outcomes will depend on having a coherent strategy supporting urban mobility (ADA, 2015). Essentially, high quality public transport (such as the Riyadh Metro) is an important element of the mobility strategy that maintains the city's economic prosperity. Nevertheless, the transport authorities in Riyadh recognise that the public transportation system was chosen based on extensive studies (see Chapter 3.4), and the best operational and tactical plans from worldwide best practice were also taken into account.

In this chapter, the future transport scenarios for Riyadh which were extracted from qualitative analysis were tested to study the full impact of each one. These scenarios were based on three hypotheses and were dropped into the composite OPCs, with the following results.

Scenario 1, do nothing, is an option that does not serve the current Riyadh network at all. According to the composite OPCs, once the current road network reaches an additional 30% of its current traffic volume in 2021, Riyadh will be at saturation point due to current travel patterns, dominated by private car use (as discussed in Chapter 2). Thus this scenario will increase the city's traffic problems.

In Scenario 2, there is no doubt that public transportation is the key solution for Riyadh's transport problems from the point of view of transport key stakeholders and this research. According to the composite OPC curve, this solution helps solve network problems by removing between 43% (following the best figure from among international cases) and 7.2% (the lowest figure of international cases) of traffic volumes. Policy transfer and implementation are the key factors in achieving the best results in this scenario.

Scenario 3 (PCR) must be used alongside public transport in Riyadh to solve congestion problems and help reduce traffic volumes. According to transport authorities in Riyadh (see Chapter 4), there are many plans to be developed after the launch of the Riyadh Metro. For example, car parking remains free of charge, which should be changed to

encourage people to dispense with their cars, and is generally sufficient, although capacity and convenience are becoming more of a problem in some areas, particularly at the busiest times of day.

In Scenario 4, this research emphasises that replanning land use within the city will significantly reduce traffic volumes in parallel with the above scenarios. Although the most optimistic hypothesis in this scenario is a 7% reduction on the network, this research is much more optimistic than that due to the current tendency of the Saudi government to establish and develop sub-centres and housing projects (see Chapter 3). Table 7.8 shows the impact of each strategy on other cities worldwide compared with the estimates for Riyadh.

Table 7.8 The impact of each strategy on other cities worldwide compared with the Riyadh estimation (Original: Author)

		Congestion solution		
City		Public transport	Private car reduction	Replanning land use
London		43%	18%	Developed cities 2% average, figure varies within developing cities
Paris		39%	18%	
Los Angeles		10.2%	4%	
Portland		27%	11.9%	
Kuala Lumpur		16%	-	
Stuttgart		29%	-	
New York		21%	27.7%	
Riyadh estimate	High	43%	27%	7%
	Mid	25.1%	16.1%	4.5%
	Low	7.2%	4%	2%




Traffic congestion has become a huge problem in metropolitan cities putting them under huge pressure. From the research perspective, it is possible to achieve the best solution to this problem through three key solutions which are:

- 1) A high-efficiency public transport system serving all parts of the city
- 2) Private car reduction strategies which reduce traffic volume as much as possible
- 3) Replanning land use to help integrate it with urban transport to achieve a sustainable transport system

As a result of differences in culture, demographics and travel behaviour, these solutions vary from city to city, and from country to country. Thus this research has demonstrated that the most important aspect of these solutions is how to transfer policy and implement it from elsewhere. Indeed, policy transfer is the milestone of any solution. As mentioned in Chapter 3, policy transfer is a multi-faceted science that needs a multidisciplinary and detailed approach to obtain the best results.

In summary, this research identifies the key solutions for congestion and urban transport problems within metropolitan cities such as Riyadh in the following table (7.9), in which calculate the proportion of all solutions as key contributors in seeing how even small differences in expected outcomes could lead to quite significantly diminished effects.

Table 7.9 Key congestion solutions (Source: Author Original)

	Public transport	Private car reduction	Replan land use
Solution			
Features	<ul style="list-style-type: none"> ✓ Safe ✓ Comfortable ✓ Door-to-door accessibility ✓ Perfect timing ✓ Simple to understand and use ✓ Reliable ✓ Frequent ✓ Reasonably priced <p>(Source: Europe Directorate General for Energy and Transport, 2010)</p>	<ul style="list-style-type: none"> ✓ Road pricing ✓ Congestion charge ✓ Traffic demand Management ✓ Licence limitation ✓ Fuel taxation ✓ Limited parking <p>(Source: Author)</p>	<ul style="list-style-type: none"> ✓ Integrate new developments with the transport system ✓ Transfer big centres to the suburbs ✓ Building licence limitation ✓ Comprehensive study of road network to includedetermining roads' LoS and studying impacts of road junctions <p>(Source: Author)</p>
Contribution ratio to solving congestion problems*	56%	35%	9%

* The contribution ratio was taken from the average ratio of the international cases for each scenario mentioned earlier in this chapter

7.5 Conclusion

This chapter contributes to the overall research objective **of investigating the performance of future scenarios when implemented in the composite OPCs**. The specific research questions to be answered by this chapter are as follows:

Research question 15: To what extent the extracted future strategies can address Riyadh's traffic problems, and whether these strategies can be successful when combined or separate.

This research derived four approaches to solving Riyadh's traffic problems from key Riyadh stakeholders. These scenarios are; a) do nothing, b) public transport, c) reduce private cars, and d) re-plan land use. Apart from the 'do nothing' option, which serves as an analytical baseline, the remaining scenarios do have the potential to address various traffic pathologies, as measured by four key network performance indicators.

Policy transfer is key. If policies transfer and are implemented effectively, and the scenarios mimic best-cases internationally, the effects will generally exceed Riyadh stakeholder expectations. If policies do not transfer as successfully, and again mirror other selected international cases, then outcomes will be less effective than currently forecast. The range of policy transfer possibilities can be summarised as follows:

- Public transportation: This solution has the potential to remove between 43% - 7.2% of private cars. Current estimates for Riyadh are 20% when operated.
- Private Car Reduction PCR: This solution has the potential to remove between 37% -4% of private cars. Current estimates for Riyadh are not available.
- Re-plan land use: This solution has the potential to remove between 7% -2% of private cars. Current estimates for Riyadh are 7% or more due to accelerated Urban Growth.

The research finds that maximum benefit can be accrued when these scenarios are combined. In particular, an effective Private Car Reduction strategy relies heavily on Public Transport and Land Use Replanning.

In summary, then, and in answer to the research question about the extent to which the extracted future strategies can address Riyadh's traffic problems, the answer is affirmative. These scenarios do have the potential to resolve Riyadh's current traffic difficulties as follows:

Solutions	Public transport	Private car reduction	Replanning land use
Contribution ratio to solve congestion problems*	56%	35%	9%

* The contribution ratio was taken from the average ratio of the international cases for each scenario.

Research question 16: In what way are policy transfer issues manifest in the SMM results, and do they challenge existing assumptions.

Policy transfer issues are key to the performance of the future scenarios, they are manifest in the SMM, and they challenge existing assumptions. At the very least, they demonstrate that policy transfer is a key risk to the success of mega projects like the Riyadh Metro. The composite OPCs provide a numerical analysis of congestion indicators such as queue length, vehicle flow, journey time, and LoS grade. What emerges is the key finding that the network is in a critical state.

For example, a mere 2% shortfall - in PT ridership, will increase the mean queue lengths by 5 meters, LoS will decrease with v/c ratios going from 0.81 to be 0.89, and average journey will be longer by approximately 6 minute. The composite OPC curves show that the network is sensitive to small changes in traffic volumes, changes which are well within the scope of policy transfer and implementation issues. This is why they

represent a key risk. As a result of different cultures, demographics and travel behavior, these solutions vary from city to city, country to country, thus, this research has demonstrated that the most important aspect of these solutions is how to transfer policy and implement it from elsewhere? Indeed, policy transfer is the milestone of any solution.

CHAPTER 8 Conclusions

8.1 Summary

This research makes a substantial, original contribution to knowledge in four key ways. Firstly, it puts the aspirations of Riyadh's current and future transport strategies in contact with an important, and hitherto neglected, area of research: policy transfer. This is defined as a best practice for resolving/addressing specific issues within a city/country in a way which makes it a worthy model for others to follow when emulating similar issues. (Peck, J. 2011). Policy transfer carries a significant risk in importing strategies and expertise from other contexts in the expectation they will yield similar or greater benefits when transplanted to a different context, in this case Saudi Arabia.

Secondly, the research captures information directly from key Riyadh transport stakeholders and contextualises the current Riyadh transportation approach within a broader historical, cultural, and technical perspective drawn from other world-leading cities. Thirdly, the research deploys traffic microsimulation on a scale, and in a way, which are unique. The Riyadh city core has been characterised with newly developed Overall Performance Curves (OPC), meaning that not only can the current policy transfer scenarios be tested, but all possible future scenarios. Fourthly, and finally, these largely qualitative insights are effectively integrated with a quantitative, agent-based modelling approach. In a unique step, this permits a direct test of policy transfer-derived transport hypotheses. Thus, this research provided an opportunity for engineers, city planners, transport systems stakeholders/decision makers and beneficiaries to SEE the future might look like now.

Riyadh is a unique case study due to its Islamic-Arabic culture, its location in the middle of the desert and its climate with very hot summers reaching 55°C and freezing winters below 0° C. For these reasons, among others, road transport dominates in Riyadh. More than 93% of journeys are made using private cars. In these important respects Riyadh is a unique case study. At the moment, transport in and around the city is time-consuming, unsafe, unhealthy and ultimately unsustainable.

Congestion has become part of daily life in many areas of the city. This has a number of negative effects, including reduced productivity and ‘quality of life’ and atmospheric contamination (Farahani et al., 2013). For transport users, the consequences are often extreme levels of congestion, with lengthy delays on main routes within the city. To address Riyadh’s transport problems, several high profile projects are underway, most notably the Riyadh Metro, currently the world’s most expensive metro project with a total value of SAR 88 billion (ADA, 2015).

This is an exciting time to be working in the Saudi Arabian transport context. It is also clearly the case that solutions to these real-world problems lie within and beyond several linked disciplines. As a result, this research has had to operate from a strong multidisciplinary platform, connecting transportation engineering, planning and urban studies to explore the issue of policy transfer as it applies specifically to Riyadh. To help achieve its aims, this research has a set of themes and objectives and a series of defined research questions outlined in Chapter 1 and restated in the table below:

Table 8.1 Research themes, objectives and questions

<u>The me</u>	Objective	Question	Answered in chapter
<u>Policy transfer, urban expansion</u>	To understand the range of factors which have contributed to Riyadh’s current traffic situation and to analyse the causes of this problem	1) What are the main factors contributing to Riyadh’s current traffic situation that is almost 100% dependent on private car use?	Chapter 2
		2) What are the stages of development that contributed to the current form of Riyadh’s road network?	
		3) What are the current transport issues in Riyadh?	
	To understand the origins of Riyadh’s transport planning policies, and their effects over the last five decades?	4) Of all the possible configurations and transport policies Riyadh could have chosen, why these policies specifically?	Chapter 3
		5) In what way is the theoretical framework of policy transfer	

		manifest in Riyadh?	
		6) Is there a risk that policy transfer issues could arise with new 'bought in' projects such as the Riyadh Metro?	
<u>Riyadh future scenarios</u>	To generate and validate future transport scenarios with key Riyadh stakeholders	7) Where do Riyadh's traffic problems come from?	Chapter 4
		8) How are policy transfer issues manifest in current decision making?	
		9) What expectations do key stakeholders have for current and future transport projects?	
<u>Riyadh future scenarios</u>	To create and calibrate a Strategic Microsimulation Model (SMM) for the most congested part of the Riyadh City Core	10) Can microsimulation be used as a valid approach to transport planning in Riyadh, and can a model of Riyadh's city core be created?	Chapter 5
		11) How can the microsimulation model of Riyadh's city core be used to reveal the structure and character of Riyadh's existing transport challenges?	
		12) Can such models enable larger-scale policy interventions to be explored, visualised and effectively communicated to stakeholders?	
<u>Policy transfer, urban expansion, Riyadh future scenarios</u>	Create Overall Performance Curves (OPCs) that characterise Riyadh's road network performance and compare them with predictions from future scenarios	13) To what extent can microsimulation model diagnostics shed light on future Riyadh traffic scenarios?	Chapter 6
		14) What does the Riyadh transport situation look like under all possible conditions?	
	To investigate how these future scenarios perform when implemented in the SMM	15) To what extent can the extracted future strategies address Riyadh's traffic problems, and could they be successful when used separately or combined?	Chapter 7
		16) In what way are policy transfer issues manifest in the microsimulation results and do they challenge existing assumptions?	

The thesis has aimed to take the reader on a journey through Riyadh's transport history and context, revealing why it is a unique case study. Very few, if any, cities can claim their car use dominates to the same extent, and neither can other cities – relatively speaking – contemplate the financial inputs needed for large-scale infrastructure changes of the sort being introduced in Riyadh. Against this backdrop, and arising from the early chapters of this thesis, is the concept of policy transfer. This is the theoretical lens through which the thesis projects its main findings, and through which they are interpreted.

In a further unique step, the research has gathered first-hand accounts of stakeholder visions of Riyadh's future, accounts which are distilled into a number of explicit scenarios for testing. Given that policy transfer is essentially a way of theorising about the unintended consequences of transplanting policies from one culture to another, traffic microsimulation is a compatible approach for analysing these issues. This is agent-based approach to traffic modelling allows emergent (and unexpected) traffic behaviours to be observed and measured. The scenarios drawn from the Riyadh stakeholders are implemented into a model of Riyadh's city core and the results analysed.

This use of microsimulation as a strategic tool is quite new. From this analysis a number of insightful and useful findings emerge which go beyond our current understanding. Before summarising the constituent chapters of this thesis, it's useful to reflect briefly on its overall structure and how the multidisciplinary qualitative and quantitative branches of the research converge to give rise to a significant original contribution to knowledge.

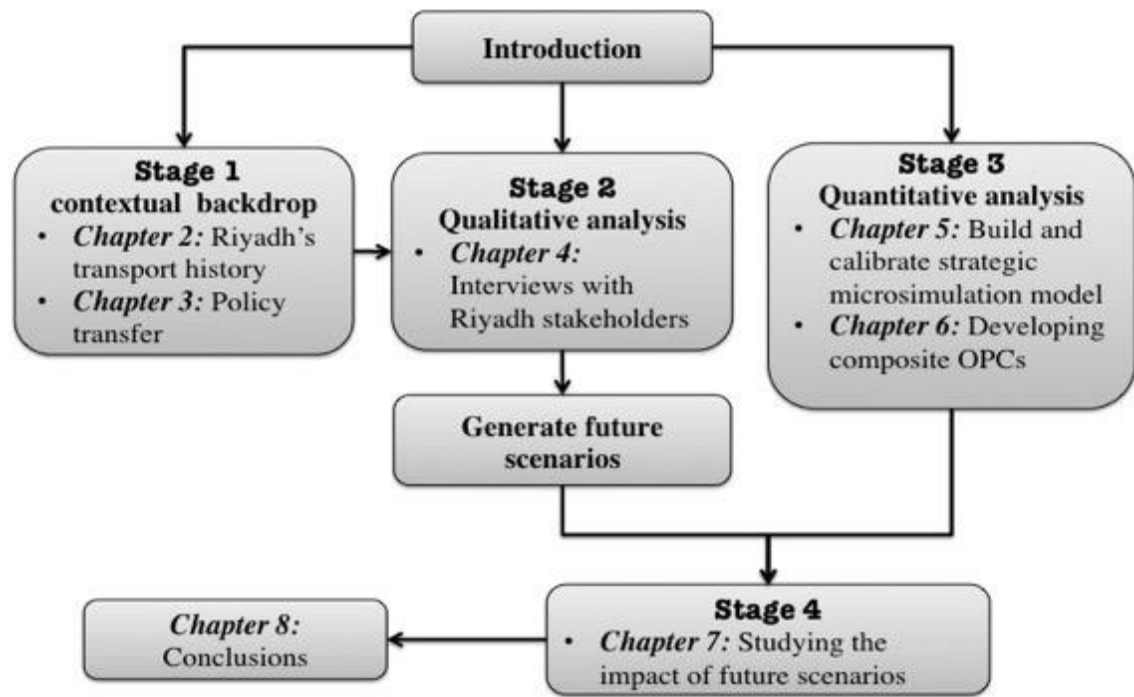


Figure 8.1 Research structure

As shown in Figure (8.1) the research has been structured in four main stages, which can be summarised as follows:

Stage 1: Contextual backdrop

This stage helps the research to understand the factors affecting Riyadh's transport planning, including:

- Introduction to the thesis including the problem statement, research objectives and research methodology
- Investigation of the main aspects of transport and urban planning that have contributed to Riyadh's traffic current situation which is almost 100% private car use
- Focus on and analyse the policy transfer concept and key issues

This stage creates the main axes of qualitative analysis which will be discussed in the next section.

Stage 2: Qualitative analysis

This research gained privileged access to key stakeholders in the Riyadh transportation sector, from government-level decision makers to practising transportation professionals. This qualitative research step helps to contextualise the current Riyadh transportation approach within a broader historical, cultural and technical perspective. These interviews then contribute to the development of future scenarios for testing in the Strategic Microsimulation Model (SMM) of Riyadh's city core. These insights help to provide high levels of external validity for the thesis, meaning the scenarios to be tested will be recognisable to research end-users.

Stage 3: Quantitative analysis

During this stage, the research presents the main steps of design, development and calibration of the SMM. This model serves as the experimental platform for testing key aspects of urban planning theory and the resulting practical solutions for the most congested part of Riyadh city centre. The software developers formally audited this model, a step routinely applied in commercial practice.

The research then repeatedly ran the SMM under all conditions of traffic flow, ranging from an empty network to full saturation, to assess the Riyadh road network against four performance indicators. These were; Level of Service (LoS), traffic flow, journey time and queue length. The ways these indicators changed under all possible flow conditions were represented as Overall Performance Curves (OPCs). These are the final product of the modelling stage, serving the thesis as test bed for all future transport scenarios.

Stage 4: Examining scenarios

Having developed OPCs for all indicators, it was then time to drop the forecast future scenarios extracted from Stages 1, 2, and 3 onto the OPCs to study the impact of each one. In other words, whatever the scenario expectations, they will be somewhere on the OPCs. At this stage, the research reviewed international best practice/facts for each scenario to help determine how realistic each one was under the policy transfer conditions as they applied to Riyadh. Low, medium and high policy transfer estimates were tested and compared with current Riyadh predictions where these existed.

8.2 Summary of research chapters

Chapter 1: This introduced the thesis by presenting the Riyadh context, and defining the problems, and listed the main research questions and scope including the research aims and objectives. Next the research began the **qualitative analysis** by diving in deep with the case study to understand the casual causes behind Riyadh's current situation.

Chapter 2: This chapter contributes to the overall research objective by developing an understanding of the range of factors behind Riyadh's current traffic situation, which is almost 100% dependent on private car use. It also presents the stages that contributed to the current form of Riyadh in terms of its road network, including an analysis of current public mobility services and issues. The main issues discussed in Chapter 2 were: a) **Existing road network patterns:** These resulted from Riyadh's master plan designed by Doxiadis in the early 1960s. Moreover, the need for rapid expansion was the Saudi government's desire for such plans to cover its needs and development.

Doxiadis designed the city to rely mainly on private cars, which led to the lack of public transport use, b) **Current public transport services:** The lack of public transport services is the result of increased private car use. Several factors led to this lack, which can be summed up as follows: the Saudi Arabian Public Transport Company (SAPTCO) is the main carrier in the kingdom across and between cities, and the lack of regard for

female privacy. In particular, the design of bus interiors and seats are not appropriate for Muslim women or families, and it is culturally unacceptable to share a seat or to sit very close to male travellers who are not relations. Jitneys, which mainly serve the market for labourers and itinerant workers, do not carry women. However, the introduction of public transport itself is not enough to attract ridership. Given that there is direct “competition” between public transport and private car use, the car ‘wins out’, not on just convenience and cost, but also on comfort in a hot environment, and privacy in a society that strongly values this; c) **Car ownership issues:** As mentioned previously, all the above factors have contributed strongly to the increase in private car use, alongside other casual factors which have been discussed in detail in Research Question 1.

The Doxiadis master plan, indeed, the very notion of a ‘master plan’, is itself an example of policy transfer. In this case, it is an example of largely American best practice being applied to the Saudi Arabian context. The Doxiadis master plan is one of the main factors responsible for Riyadh’s current form. The theoretical foundations of the policy transfer concept are discussed in the following Chapter.

Chapter 3: Given what was found in Chapter 2, it was important to explore the policy transfer process as a theoretical framework. How can these policies, which were transferred from different (mostly Western) cultures, fit within the Saudi Arabian context? As previously mentioned, the risk of bought-in plans (such as the Doxiadis one) has had a major impact on Riyadh’s form and has been the main contributor to Riyadh’s dependency on private cars as the main mode of transport. So, this Chapter has analysed the policy transfer as concept and its theoretical framework.

Policy transfer is defined as transferring urban plans/solutions that have facilitated or resolved an urban issue somewhere implemented for the same perceived issue elsewhere (Dolowitz et al., 2000; Hoyt, 2006; Martínez, 2004). According to Martínez (2004), policy transfer is an ancient phenomenon, especially, in the field of public administration, and there are wider examples of administrative reforms and innovations which have been transferred from one national or regional context to another. Martínez

(2004) concludes that three factors that can produce policy failure in a transfer process: a) Uninformed transfer, b) Incomplete transfer, and c) Inappropriate transfer.

The research has found that understanding the theoretical framework policy transfer is key to the success of any plans for the future. This enables the research to confront a potentially critical risk for Riyadh, that new 'bought-in' or 'off-the-shelf' projects, of which the Riyadh Metro is a leading example, may not succeed within the Saudi context, and may not perform as expected despite 'success' in other cities. This chapter sheds light on the theoretical framework, but what does it look like in practice? The next chapter will conduct interviews with decision makers in Riyadh's transport sector.

Chapter 4: Chapter 4 aims to help the researcher understand: a) What the policy picture is in Riyadh, b) How policy transfer issues are manifest in current decision making, and c) Key stakeholders' expectations for current and future projects. A series of semi-structured interviews conducted with key stakeholders in Riyadh's transportation sector helped generate future scenarios for the city.

The main findings of these conversations were: a) The causes of Riyadh's congestion included: poor planning, a lack of public transport, large-scale projects, parking, private car dependency and social trips, b) Congestion solutions include: public transport, private car use reduction policies and replanning land use. In addition, participants noted that all departments must cooperate in facing Riyadh's traffic problems, c) It's important to encourage the public to use new public transport services. Indeed, this is key to their success, and a critical aspect of those policy aspects which definitely need to transfer. These results have been interpreted into Riyadh's future transport scenarios as follows:

- 'Do nothing' scenario
- Efficient public transport scenario
- Private Car Reduction (PCR) strategy
- Replanning land use

These scenarios will be directly under by the quantitative analysis which will be operated in the next chapter.

Chapter 5: In this chapter, the research started the **quantitative analysis** by developing the SMM for Riyadh's most congested area. As mentioned above, microsimulation is a new and increasingly popular transport planning method. It is an Agent-Based Modelling (ABM) approach which involves creating computer models of real road networks and their traffic and running those models many times to detect emerging trends in factors such as queues and congestion. The model itself is approximately 1.3km by 7.4km and simulates approximately 40,000 trips over a two-hour period between 0630 and 0830.

The SMM was created and calibrated as a product of commercial, professional quality for research purposes to imitate real-world traffic congestion in Riyadh, and the software developer SIAS Ltd tested and reported the model. Furthermore, SMM results show the main indicators for measuring congestion, which were: a) Level of Service LoS, b) Traffic flow, c) Journey time and d) Queue length. Using model iteration, the values of the respective indicators were logged and these, in turn, represented coordinates for so-called Overall Performance Curves (OPCs) that will be justified and properly explained in the next chapter.

Chapter 6: This chapter has shown how the SMM of Riyadh's city core responds to different traffic levels on a range of different indicators, Level of Service (LoS), traffic flow, travel time and queue length, to generate the OPC. OPCs are created by running the SMM multiple times, with a different car volume matrix used at each model iteration. This was achieved by increasing the underlying Origin/Destination O/D matrix values from 0 car volume to 100% additional car volume in 10% stages. This enabled the effects of all possible scenario assumptions on the network to be visualised. OPCs are graphical representations showing how the network performs under all conditions. With the network thus characterised, it becomes possible to scrutinise the expected and actual outcomes to be derived from the range of future scenarios which the key Riyadh transport stakeholders identified.

Chapter 7: The research then integrated the qualitative and quantitative approaches to map the future scenarios on composite OPCs to explore the extent to which the extracted future strategies addressed Riyadh's traffic problems and whether they could succeed when used separately or combined. Moreover, it explored the way policy transfer issues manifested themselves in the microsimulation results, and whether they challenged existing assumptions.

The research identified four scenarios for Riyadh's transport future, which are as follows:

- **Scenario 1: Do nothing:** This scenario will increase problems in Riyadh where the network will become fully saturated in 2021, four years after writing this research.
- **Scenario 2: Effective public transport:** This scenario has a significant impact on the network by reducing 43% of the current traffic volume if this policy is applied and passed successfully (in line with the best global example of London) or will be less influential up to 7% Dubai if the policy failed. Although the Riyadh authorities' expectations are 20% of the Metro ridership, this research confirms what the authorities expect in Riyadh due to the current circumstances described in Chapters 3, 4, and 7.
- **Scenario 3: Private Car Reduction (PCR):** This scenario is a set of strategies that contribute to reducing private car usage including: road pricing, congestion charges, Traffic Demand Management (TDM), licence limitation, fuel taxation and limited parking. This scenario contributes to solving network problems by removing from 25% to 14% of the current traffic volume.
- **Scenario 4: Replanning land use:** This scenario has an impact on improving the current network by removing from 7% to 2% of the current traffic volume.

According to the OPCs, the network is highly sensitive to policy transfer issues, and a slight change in policy transfer will have a significant impact on the OPC curves.

8.3 Research question results

To achieve the research objectives, a set of specific research questions were developed in Chapter 1 which the thesis sought to answer. These questions are specified and distributed through the chapters of the thesis. They have been answered in detail within the respective chapters, but can be summarised as follows;

Research Question 1: What are the main aspects of transport that have contributed to Riyadh's current traffic situation, in which almost all residents depend entirely on private car use?

Riyadh's population explosion and increasing economic activity have given rise to a corresponding growth in mobility. This, alongside several other important structural and cultural factors, has generated high levels of car ownership and use. However, the research found the following main contributing factors to Riyadh's current traffic situation::

- **North American patterns of urban development**

Saudi cities resemble American patterns of urban development and transportation more closely than those of western Europe. Many cities, especially in North America, have decentralised homes and jobs, leading to growth in suburb-to-suburb commuting, and a corresponding shift from public transportation to the private car.

- **Cheap petrol**

A major factor in Riyadh's car dominance is that petrol is cheap. At the time of writing, a litre of petrol in Saudi Arabia costs USD 0.2 compared with USD 1.45 in the UK and as high as USD 0.62 in the US. Fuel prices, therefore, are not the barrier to private car use in Saudi Arabia that they might be elsewhere. This is because Saudi Arabia is the

one of the world's largest oil producing nations.

- **The kingdom's economic and demographic features**

Private cars are affordable to many people, including those on a lower income, and this largely compensates for the lack of an effective public transport system. Moreover, people who do have access to cars simply never use public transport. This availability of private cars and their low running costs contribute strongly to private car usage. In terms of the economic aspects, Saudi Arabia has experienced sustained economic growth, which has attracted migration from within the country and from outside it.

- **The effects of the climate on walking**

Riyadh's climate is very hot in summer and cold in winter, and characterised by year-round low humidity, especially in the summer. Equally, day and night-time temperatures vary considerably. High car dependency is in large part determined by these climatic conditions.

Research Question 2: What are the stages that contributed to Riyadh's current form in terms of its road network?

During the 1960s, the Saudi government began creating the first master plan for Riyadh. The Greek American consultant planner Doxiadis was appointed to design it. Doxiadis's plan was well adapted to private car use, as were many similar master plans used elsewhere in the 1970s. Doxiadis designed the new city centre to the north of the old city because of the need to build more service buildings (ministries, government departments etc.). In Riyadh, according to the Doxiadis master plan, activity spines were proposed, each to be serviced by mass freeways.

There was a corresponding need to build more residential neighbourhoods and activity centres, and so an overall increase in demand for travel had to be served more efficiently. The means by which this demand could be serviced was the private car (Al-Dubikhi, 2007). One interesting feature of the Doxiadis period was that Riyadh's citizens could buy a house on land in the new city under the availability of money made during the oil boom. This, too, had a significant effect on trip types and mode choices which remain to this day.

Research Question 3: What are the current public mobility services and issues?

In Riyadh, public transport provision is generally poor. It is mainly offered by the Saudi Arabian Public Transport Company (SAPTCO), established in 1979 as a public company (Al Gadhi, 1994). Unregulated transport services compete with the state provider, but both are mainly used by itinerant workers and labourers. In both cases, though, public transport only serves a narrow market. Most notably, there's an almost complete absence of female service users, who are put off by the lack of privacy and other factors which run counter to Islamic and Saudi norms. Lessons learned worldwide show that introducing public transport is not enough in itself to attract ridership

This is even more apparent in Riyadh. Despite this, Riyadh's transportation plans are founded on a public transport concept, namely the Riyadh Metro project. The aim is to revolutionise the way the city's inhabitants, and the hundreds of thousands of visitors who come here each year, travel around the capital (Al-Dubikhi, 2007).

Research Question 4: Of all the possible configurations and policies Riyadh could have chosen, why chose these ones specifically?

The research found that the kingdom's approach to planning mirrored that followed by developing countries at that time. During the 1960s, given the availability of capital and the lack of relevant experts, Saudi Arabia's government attracted many Western

consultants to develop and solve urban problems. Perhaps the most important of these plans was the master plan designed by Doxiadis. This master plan played the main role in Riyadh's current urban form, which has adopted the private car as the main mean of transport.

According to Peck (2011), policy transfer is defined as a best practice to resolve/address specific issue within a city/country which is worthy model for others to be taken for similar issues.

The approach of contracting Western consultants to design the master plans was popular in many developing countries, due to the shortage of relevant experts (as mentioned previously) in the urban planning field. In policy transfer terms, this reflects the notion of a 'specialist elite'. Master plans themselves constitute comprehensive land use and infrastructure development plans, projected in tune with vigorous national economic growth schemes, all of which seek to facilitate economic prosperity and social stability by manipulating the spatial system.

The master planning approach operated on a large scale, and was favoured over localised 'organic' solutions as a way of bringing about efficient, almost 'machine-like' cities. They were also archetypal solution (in other locations) to rapidly expanding cities. They were long-range, multi-phase conceptualisations of a town's growth. To that extent, master plans are examples of 'governmentality' which fitted well with the hierarchical nature of Saudi Arabian governance.

Research Question 5: In what way is the theoretical framework of policy transfer manifest in Riyadh?

Riyadh has experienced rapid population and spatial growth, land use change and infrastructure development over the last 40 years. Various driving forces have caused spatial changes over time, mainly economic progress, population growth, government

attitudes, the city's master plans and the growth of transportation infrastructure. Riyadh exhibits two different features of urban growth, which can be identified as sprawl expansion and outward growth. It was found that the growth of the transportation infrastructure had been influenced mainly by population growth (Mubarak, 1992).

Not only is policy transfer manifest in the solutions to Riyadh's transport challenges (e.g. a 'specialist elite' and 'governmentality'), but these challenges were at all aspects of the urban development, which were often not in line with Saudi culture or socio-privacy. The demographic and Islamic situation of Riyadh reflects these challenges as a critical risk in the transfer of urban policies. Governmental needs to development which is fully founded was the reason behind policy transfer in Riyadh. Officials (including Riyadh's Mayor, the Municipality and Ministry of Municipal and Rural Affairs (MOMRA)) are involved and fully responsible for urban policies and the planning process.

These policies were taken from the global best practice of the 'specialist elite' due to the shortage of local knowledge. Indeed, there are a number of questions concerning policy transfer. In terms of the theoretical debate, these questions were summarised within a policy transfer framework developed by (Dolowitz & Marsh (2000)), and these question are: Why transfer? Who is involved in the transfer? What is transferred? From where is the policy transferred? What is the degree of transfer, and what are the constraints on transfer? How can we demonstrate policy transfer? How can transfer lead to policy failure? The model has been developed to classify the different types of policy transfer and the different results these can produce

For example, accurate data on where the policy comes from and how to transfer it helps to consider the specific characteristics of this society and thus to avoid failure. Moreover, this model has been applied to Riyadh to answer the policy transfer theoretical questions of the Dolowitz model mentioned earlier.

Research Question 6: Is there a critical risk that specific policy transfer issues could arise with new 'bought-in' projects such as the Riyadh Metro?

By mapping the existing policy transfer theory to the situation pertaining to Riyadh and extending existing theory to take account of Saudi's unique socio-cultural and climatic factors, the research has analysed a potentially critical risk for Riyadh: that new 'bought-in' or 'off-the-shelf' projects, of which the Riyadh Metro is a leading example, may not be appropriate to the Saudi context and may not perform as expected despite 'success' in other cities.

Yes of course, there is a serious criticism levelled at policy transfer/'bought-in' plans which include a wide range of social, demographic and economic aspects as well as social ones including culture and privacy. This chapter? has considered three aspects of the failure of the Doxiadis master plan. These aspects are: a) Population growth, which has jumped sixfold beyond the Doxiadis growth forecast; b) Street patterns that affect city form and c) Integrated public transport.

Furthermore, Chapter 3 has defined policy transfer and represented its implementation across the Arab world and in Riyadh specifically. Thus, the planner must consider policy transfer issues and their implementation to avoid the potential failure of any 'bought-in' projects (such as a new master plan, road networks or railways). In addition, this research has found that the network seems very sensitive to policy transfer issues, and that even a slight change in policy transfer issues will have significant implications (as fully described in Research Questions 15 and 16).

Research Question 7: Where have Riyadh's traffic problems come from?

There are six main causes of congestion in Riyadh, from the viewpoint of stakeholders:

- Poor planning, meaning Riyadh has adopted the private car as the main method of transport
- A lack of public transport in terms of poor services, which has been covered in

Research Question 3

- Constructing Large-scale projects - under the availability of capital, the Saudi government built and developed many mega projects such as King Abdullah Financial District (KAFD), Media City, the Riyadh Metro, etc.
- Free parking
- Private car dependency
- Social trips.

According to the interview analysis, the lack of a public transport system has reached 26% of the problem, which is the highest cause of traffic jams, and has a direct influence on private car use. This is clearly the reason behind the Riyadh Metro project.

Research Question 8: How are policy transfer issues manifest in current decision making?

Saudi Arabia has a conservative approach to society and the state, due to its religion and culture. The Constitution of Islam forms the basic rule of law for all regimes. The decision makers involved in developing transportation projects in Saudi Arabia have full autonomy in dealing with such projects, including the often bold use of new technology and best-practice approaches from around the world.

On the other hand, these approaches are overseen by higher levels of government, specifically the Ministers' Council and the Royal Court, to ensure the potentially conflicting concepts of globalisation and Islam are resolved in ways that suit Saudi culture and governance. These policies must be well suited to the cultural and demographic situation of the Saudi context. Saudi Arabia is a country that supports large families and polygamy, while valuing the privacy of women who do not want to share a seat with men to whom they are not related.

One good example of this is that new trains typically incorporate the latest technology and high-quality engineering, provided by well-established (usually Western) providers,

but they must also incorporate family sections to maintain occupants' privacy, alongside similar sections dedicated to female travellers, in keeping with local cultural norms.

Research Question 9: What expectations do key stakeholders have for current and future transport projects?

The interviewees know that the Riyadh is growing and developing rapidly, and that if public transport policies were introduced in the city, this would force changes in travel behaviour. They also imagine that Riyadh will become a world-class city within the next decade. They expect to see many new projects to serve transport system in the Saudi capital. These projects include public transport, such as the Riyadh Metro and city buses, the development of the current plan commensurate with the city's need for sustainable urban transport, establishing new suburbs that will serve about a million people and private car use reduction policies, such as road pricing and the addition of fees and restrictions on licenses etc.

The interviewees confirmed that new projects such as the Metro and city buses will definitely reduce congestion. New modes of transport will be user and environmentally friendly. Moreover, they'll be implementing these strategic plans and projects while drawing on ongoing studies and research to develop solutions similar to those seen in capital cities worldwide.

Research Question 10: To evaluate microsimulation as an approach to transport planning, the development of a microsimulation model of a transport corridor in Riyadh, and its calibration to live traffic situations

The model has been created via Paramics microsimulation software, since this helps to achieve the aim of making both a theoretical and practical contribution to the existing knowledge. Accordingly, nine major steps were implemented in an effort to achieve the necessary outputs from the model: Identification, Data collection, Coding, Error

checking, Model creation, Calibration, Testing of alternatives, Documentation and Presentation. The SMM was calibrated in several stages to ensure the model was validated in line with current best practice for the industry. This includes a formal model audit which SIAS Ltd performed. One new way of visualising and modelling the complex interactions between policy interventions and individual transport user behaviours is to use traffic microsimulation in this way.

Research Question 11: How can the SMM be used to reveal the structure and character of Riyadh's existing transport challenges?

The model itself is 1.3km by 7.4km, and simulates approximately 40,000 trips over a two-hour period between 0630 and 0830. SMM observation is an important feature of microsimulation, and one of its key benefits. It's a way of communicating complex system ideas and results to stakeholders. They can see the emergent phenomena and complexity for themselves. The results show that the main key features of existing network are:

- Substantial queuing (in terms of time spent waiting) from King Fahd Road (KFR) to King Abdullah Road (KAR) and Imam Road (IR) inbound and outbound at 0715
- Substantial queuing (in terms of number of vehicles) at KFR Northbound at 0730, the highest volume is on KFR, KAR and IM
- Most congested junctions are IM eastbound via KFR, and KAR westbound via KFR at 07055
- The most congested lanes are Lanes 1 and 2 of KAR and Lanes 1 and 2 of Mohammed Street (MOH) + Lanes 1, 2 ,3, and 4 of IM travelling towards KFR at 0710.

Research Question 12: What is the role of such models in exploring and visualising larger-scale policy interventions and communicating them effectively to stakeholders?

The microsimulation model allows real-life conditions on the existing road network to be imitated. This simulation provides a broad and comprehensive view for stakeholders to consider the network's current problems, and the likely consequences of transferring any policy. (For examples of policy transfer issues: see Question 14).

Microsimulation captures the behavioural aspects of transport networks and allows them to be observed, and as such has proven invaluable in studies of ITS facilities and strategies, changing land use patterns, junction design, signal timing and much more, including policy transfer effects. Indeed, one identified research need in the policy transfer literature is for new modelling approaches, and the SMM responds to that need. Yet this exciting tool is currently completely lacking in Riyadh.

The vehicles within the model are endowed with behaviours (such as their origin/destination, speed, following distance etc.), and allowed to interact with each other on a digitally modelled road network that is geometrically referenced to the real thing (Brien et al., 2015).

Research Question 13: To what extent can the OPCs measure future scenarios on Riyadh's road network in comparison with the current status?

OPCs of the study area provide a wide range of useful and interesting diagnostics. Principle among these are the twin findings that a) the curves are non-linear and changes in total car volumes will have disproportionate effects on the key indicators, and b) the network is already in a critical state and highly sensitive to future increases in vehicle volumes. This is a graphical characterisation of how the Riyadh city core performs under a wide range of conditions, including those anticipated to occur under all conceivable future transport scenarios.

This representation is designed to be a valuable diagnostic aid for all future thinking and reasoning about Riyadh's future transport strategy. It's also an approach which could be used for any other city. OPCs are graphic representations showing network performance under all conditions. The effects of all future scenarios and their potential implementation in Riyadh's road network can be placed on these curves and conclusions drawn.

Research Question 14: What does Riyadh look like under all possible traffic conditions?

The OPCs show an inverse relationship between the Origin/Destination (OD) matrix volumes and performance on the indicators. This relationship is going to worsen when car volumes in the OD matrix increase. As shown in the following figure, the increase in the OD matrix has a rapid impact on OPCs, particularly queue length, which is almost double that of the current situation, along with double the journey time.

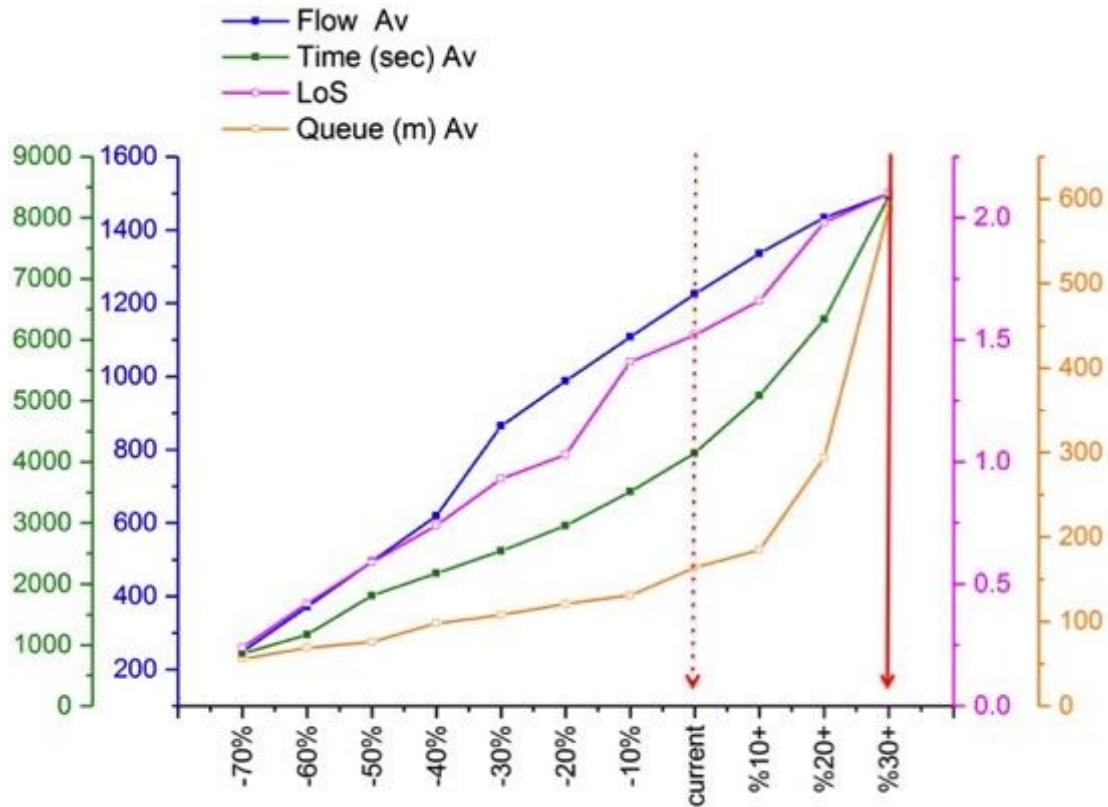


Figure 8.2 Composite OPCs for Riyadh's current situation

Equally, it shows that in all the curves there is a critical point where the most rapid changes in the indicators occur. Additionally, the OPCs show that Riyadh's existing network is already almost overloaded, and becomes completely saturated when traffic volume increases by just 30%. This is forecast to happen in a mere four years' time. Importantly, however, on all the curves there is a critical region where the most rapid changes in the indicators occur.

This is vital information in the context of large-scale infrastructural improvements and policy interventions. Understanding how transport network performance varies under different traffic conditions is an essential factor in evaluating the condition of the network and in formulating further improvement potentials. The OPCs show that Riyadh's existing network is already in a critical state, with only small further increases required to worsen the current situation - dramatically in some cases.

Research Question 15: To what extent can the extracted future strategies address Riyadh's traffic problems, and can these succeed when combined or separated?

This research derived four approaches to solving Riyadh's traffic problems from key Riyadh stakeholders. These scenarios are: a) Do nothing, b) Public transport, c) Reduce private car use, and d) Replan land use. Apart from the 'do nothing' option, which serves as an analytical baseline, the remaining scenarios do have the potential to address various traffic pathologies, as measured by four key network performance indicators.

Policy transfer is key. If policies transfer and are implemented effectively, and the scenarios mimic best-practice cases internationally, the effects will generally exceed Riyadh stakeholder expectations. If policies do not transfer as successfully, and again mirror other selected international cases, outcomes will be less effective than currently forecast. The range of policy transfer possibilities can be summarised as follows:

- **Public transportation:** This solution has the potential to remove between 43% and 7.2% of private cars. Current estimates for Riyadh stand at 20% when it is launched.
- **Private Car Reduction (PCR):** This solution has the potential to remove between 37% and 4% of private cars. Current estimates for Riyadh are not available.
- **Replan land use:** This solution has the potential to remove between 7% and 2% of private cars. Current estimates for Riyadh are 7% or more due to accelerated urban growth.

The research finds that maximum benefit can be gained when these scenarios are combined. In particular, an effective PCR strategy relies heavily on public transport and land use replanning.

In summary, then, and in answer to the research question about the extent to which the extracted future strategies can address Riyadh's traffic problems, the answer is that

indeed they can. These scenarios do have the potential to resolve Riyadh's current traffic difficulties as follows:

Solutions	Public transport	Private car reduction	Replanning land use
Contribution ratio to solving congestion problems*	56%	35%	9%

* The contribution ratio was taken from the average ratio of the international cases for each scenario.

Research Question 16: In what way are policy transfer issues manifest in the SMM results, and do they challenge existing assumptions?

Policy transfer issues are key to the performance of the future scenarios, they are manifest in the SMM, and they challenge existing assumptions. At the very least, they demonstrate that policy transfer is a key risk to the success of mega projects such as the Riyadh Metro. The composite OPCs provide a numerical analysis of congestion indicators such as queue length, vehicle flow, journey time, and LoS grade. What emerges is the key finding that the network is in a critical state.

For example, a mere 2% shortfall in PT ridership will increase mean queue lengths by 5 metres, LoS will decrease with v/c ratios going from 0.81 to 0.89, and average journey will be longer by approximately six minutes. The composite OPC curves show that the network is sensitive to small changes in traffic volumes, changes which are well within the scope of policy transfer and implementation issues. This is why they represent such a key risk. As a result of different cultures, demographics and travel behaviour, these solutions vary from city to city, and from country to country, thus this research has demonstrated that the most important aspect of these solutions is how to transfer policy and implement it from elsewhere. Indeed, policy transfer is the milestone of any solution.

These questions formed the basis for considering the way the thesis had contributed to the existing knowledge. In all, the research identified four key contributions, which are outlined in more detail below.

8.4 Key contribution

8.4.1 Key contribution 1: Policy transfer theoretical framework

This research found that, perhaps unsurprisingly, population growth has been the main driver in the growth of transportation infrastructure. In the past, a number of strategies and external expert theories have been imported into Saudi Arabia, and these are readily apparent, both in solutions to transport challenges and policy inputs. Often, people have expected to look forward to the same or even more extensive benefits in Saudi, but transplanting policy is not without serious risk. These risks, as applied to ‘bought-in’, transferred policies, include a broad number of social, demographic and economic factors, as well as social aspects, and issues to do with cultural and societal norms, such as privacy for women.

Yet this kind of master planning approach was widespread at the time, and preferred to localised, ‘organic’ solutions, resulting in cities which were so efficient they were almost mechanical. In other cities outside Saudi Arabia, where there was rapid growth, the master planning approach was widely used as the ‘go-to’ solution. Master planning was a long-term, multi-phase conceptualisation of a town’s growth. Such approaches are also strong instances of the government imposing authority from the top down, and this suited the hierarchical nature of Saudi Arabia’s style of government well.

The issues that can result from policy transfer form the cornerstone of all transport solutions. A multidisciplinary platform is needed to consider all the aspects, including urban, cultural, demographic and social. This research identified a theoretical framework for policy transfer as it applied to Riyadh. It also looked at the key factors contributing to the process of policy transfer, and the reasons behind them. How can there be risks when transferring a policy from a Western context to a Saudi one, even

when in-depth analysis and a clear process map are in place?

8.4.2 Key contribution 2: Riyadh stakeholders interviews

This research enjoyed rare access to some of the Saudi capital's key transport players, including government-level decision makers and transportation professionals actively working in the industry.

From the interviews, it identified four core themes:

- **Sources of congestion**

Interviewees agreed that Riyadh's traffic congestion was down to a number of varied factors, including a lack of public transport, inadequate planning, poor communication, a general dependency on private car use for all business and social travel, and ongoing large-scale developments such as shopping malls, companies and apartment complexes, which generate traffic.

- **Barriers to change**

Many of the congestion causes listed above are also potential barriers to change.

- **Policy transfer plan**

According to those interviewed, effective policy transfer will take place with a concerted effort including encouraging take-up of new transport facilities such as the Riyadh Metro, and having a clear idea of its likely impact. Awareness-raising, alongside yearly meetings and ongoing dialogue, will be equally important.

- **Change of urban sprawl and land use policies**

Suggestions included developing the master plan and creating new suburbs, looking at Transit-Oriented Development (TOD), making good use of derelict land, and strict

adherence to building regulations. In terms of solutions to the city's congestion problems, the interviewees agreed that replanning land use, reducing private car dependency and improving public transportation were key aims – so solutions can be found within the problems themselves.

The valuable insights gained from these interviews have been coordinated into a set of potential scenarios to be tested in the Riyadh Strategic Microsimulation Model (SMM), which directly tested some of the tenets of the policy transfer theory. Equally, some of the current assumptions about possible solutions to Riyadh's transport situation could be tested at the same time. The future transport scenarios for Riyadh were devised via a semi-structured interview format.

8.4.3 Key contribution 3: Strategic Microsimulation Model (SMM) created and calibrated for Riyadh City Core

Microsimulation is a new, exciting and increasingly popular tool in the field of transport planning – yet until now it has not been used in Riyadh. This research studies microsimulation as a methodology in transport planning, in which models are typically run many times so that collective patterns including congestion and queues emerge as individual vehicles interact. It is invaluable for studying Intelligent Transport Systems (ITS), strategies and facilities, junction design, signal timing, changing patterns of land use etc. One advantage is its provision of a more realistic and accurate representation of network performance, and of how drivers actually behave. Additionally, this method captures transport networks' behavioural aspects.

While microsimulation cannot capture all of human behaviour's subtle nuances, even straightforward behaviour causes complex patterns (which reflect real-world situations) to emerge. What's more, you don't have to be a transport specialist to understand the way microsimulation represents problems and solutions in an easy-to-understand, highly visual way, with powerful graphics depicting individual vehicles travelling across networks, including a range of different junctions and highway types. This research developed and calibrated the SMM of a transport corridor for Riyadh City Core to validate the scenarios for the future of Riyadh as taken from interviews with leading

stakeholders in the field. The researcher describes the design and calibration to live traffic situations of a model representing the city's most heavily congested part of Riyadh.

This model tested the relevant policy transfer effects while weighing up solutions which were specific to Riyadh. Additionally, the research looked at how the model could realistically depict the nature of the transport challenges the city faces. In particular, this test bed gave the research invaluable insights into whether solutions devised elsewhere could be applied to Riyadh with similar results, while also challenging current prevailing ways of thinking.

8.4.4 Key contribution 4: A combined approach to studying future scenarios and policy transfer hypotheses

Here, qualitative and quantitative approaches are integrated. The research has extracted future scenarios from the qualitative approach and dropped them onto composite OPCs taken from the quantitative stance and studied both. In this way, a powerful tool is created for directly testing future scenarios. That includes those which have been planned and are at the implantation stage (the Riyadh Metro being one key example), alongside scenarios following a different approach. Thus all future scenarios can be tested, whatever the expectations, and research objectives achieved effectively. This mixed approach involves following the expectations of each scenario to add or take away traffic from the network's current situation.

The composite OPCs establish how valid these expectations are, referring to both policy transfer theory and global best practice. Policy transfer issues can be examined more consistently with this type of modelling approach. And, using the OPC curves, the research shows that even small changes in policy transfer and its implementation can have a significant impact on key network performance indicators. For their part, composite OPCs show how sensitive the network is to even slight traffic volume changes, and that such changes fall well within the remit of policy transfer and implementation issues.

As an example, according to the results of composite OPCs, public transport policy will achieve ridership of 43%, which will improve LoS from its current F grade to a B grade. Other indicators will also be affected - queue length will fall by half, while average journey times will drop by two thirds if the policy is transferred and implemented successfully. However, just 7% (or less) of measurable improvement can be achieved on all indicators if policy transfer and implementation both fail.

This research takes a broad view by looking at the low, medium and high forecasts, and reflecting these forecasts off the issue of policy transfer in a bid to understand which estimates may be more or less likely.

8.5 Further research

Riyadh is a unique case study, and unique methods have been applied to the study of its transport. The research presented in this thesis covers the risk of policy transfer in Riyadh, interviews conducted with Riyadh's key transport stakeholders, creating and calibrating the Riyadh microsimulation model, and examining the impact of future scenarios through the lens of policy transfer. However, the policy transfer and microsimulation innovations started in this thesis have considerable potential to be developed further. The research thus helps to create an exciting new agenda for future study, for which the most promising avenues appear to be:

8.5.1 A strategic microsimulation model of the entire city of Riyadh

As mentioned earlier in this thesis, the SMM was created and calibrated for the purposes of this research. This model has been used as test bed for future transport scenarios and policy transfer issues. Therefore, this research recommends enlarging this model to include the entire city of Riyadh, by updating the current model and calibrating it at least every year based on automatic traffic counts and other live data. It should be used as a city-wide test bed that developers, planners, the government and everyone can use as a tool to see the future of transport in Riyadh in a way that saves money and time.

8.5.2 Network characterisation

In this research, four indicators were used to measure traffic congestion. These are: LoS, vehicle flow, journey time and queue length. Although the Paramics software provides many options and indicators which benefit researchers, this research chose these four indicators to measure traffic congestion to obtain OPCs curves that were consistent with its purposes. Therefore the research recommends using other indicators and adding them to the OPCs to obtain a wider result for all fields, including environmental, economic and engineering aspects, which will enhance the study of the impact of congestion and help to measure the impact of transport future scenarios.

8.5.3 A greater role for policy transfer

This research reveals a great role for the issues of policy transfer, which is evident in Riyadh. All projects brought from other cities in the world need to be designed with the Saudi context in mind, moreover, any urban policy plays a key role in city forms, encouraging development and Saudisation. At the moment, this research confirms that Riyadh currently looks like a huge workshop for transport projects including the Riyadh Metro, and these projects has been brought from best practice examples from all over the world. Policy transfer helps Riyadh to design a unique solution that works for them the city and nowhere else. Thus, the planner must learn the best lessons from other places, but use their own expertise and insight to modify those lessons for Riyadh's/Saudi Arabia's context.

8.5.4 Further study about women's driving

This research confirms that this decision will have a potentially significant impact on the road network and the future of transportation in Riyadh. Therefore, it recommends conducting further studies on the long and short-term impacts of female drivers once more of the necessary data is available, so that more accurate results can be obtained. That, of course, will help solve the city's transport problems and achieve a sustainable transport system. Moreover, it's also important to study the impact of women driving at

the strategic level, and this is the key to improving the policies and facilities to obtain a sustainable transport system.

8.6 Limitation

8.6.1 Lack of available and/or reliable data

The researcher needs accurate information to obtain the best results. In qualitative methodology, the researcher must reach the answers that help to meet the research's objectives. This includes choosing the right participants who have a direct relationship with the research questions, choosing the right questions and understanding what particular information is needed. Although this research uses the semi-structured interview as its main tool for qualitative analysis, as presented in detail in Chapter 4, it also confirms that these interviews may not be available to other researchers as fully described in Chapter 4.

8.6.2 Lack of prior research studies

Riyadh, as mentioned in the research, is a unique case study. Earlier research studies on the topic of transport in Riyadh are limited, although several pieces of research have been completed in this field. These, of course, form the basis of the literature review and help lay a foundation for understanding the area of research being investigated. Previous literature in the field is included in this research. But it would be better to introduce more research to give a broader scientific base.

8.6.3 Simulation software limitation

Simulation programs require critical data that may not be accessible to everyone, such as accurate information about the number of vehicles involved, origin/destination zone and the routes the drivers choose. The most important obstacles researchers face at this stage include:

Data collection and micro-setting

Identifying potential routes

Identifying the types of road network and alternative transportation methods

Identifying drivers' attitudes and positive behaviours

Driver attitude is considered the most unpredictable incidents. In addition, the requirements of diversion and trip track changing should be taken into account, especially in cases such as festivals, royal trips across the city's transport network and highway repairs. All these issues resulted in errors in the programme, and should be taken into account in advance to ensure the most accurate results.

8.7 Last words

Riyadh is a unique city, growing tremendously and continuously. The Saudi government seeks to provide all the means of comfort and well-being of the Saudi citizen. Riyadh (the capital of Saudi Arabia) has witnessed exceptional conditions in terms of demographic growth, urban development, social, and cultural characteristics. This is an exciting time to do this research in the Saudi Arabian transport context.

Through a long journey of quantitative and qualitative analysis and its integration, this research concluded that Riyadh is currently in a critical position in terms of traffic congestion and transportation and that Riyadh will become fully saturated within four years of writing this research. This research has had to operate from a strong multidisciplinary platform, linking transportation engineering, planning, and urban studies together to explore the issue of Policy Transfer as it applies in Riyadh. Policy transfer issues pose a critical threat by bringing projects that have been applied in different contexts to an exceptional context such as Saudi Arabia. This risk is shaped by new development projects such as the Riyadh Metro Project.

This research created and calibrated a strategic microsimulation model for Riyadh city core to extract four main indicators of congestion. The indicators are a) level of service, b) traffic flow, c) journey time and d) queue length. These indicators have used to characterise the network under different road conditions from a free-flowing network to a fully saturated network. And these, in turn, will represent coordinates for a so-called Overall Performance Curve (OPC).

Four scenarios were dropped onto OPCs. The first scenario to be explored is the 'do nothing' option. Current forecasts show the existing road network will be fully saturated by 2021 under the annual growth of 8%. Scenario 2 embodies the current strategy involving the Riyadh Metro and examines the expected traffic reductions. Scenario 3 Private Car Reduction strategies PCR. Scenarios 4 replanning land use. The various OPCs show how each of the indicators perform under all traffic conditions, enabling predictions about all possible future states to be explored. In other words, this research provides a scientific platform for future expectations. That's where the policy transfer issues come in, by using the OPCs whatever the expectations, it will be on OPCs somewhere.

This research makes an original contribution to knowledge by: 1) reveals a significant risk in importing urban strategies to Saudi Arabia. 2) Conducting a semi structure interviews with key Riyadh transport stakeholders to extract Riyadh's future scenarios, 3) create and calibrate strategic microsimulation model for Riyadh city core. Riyadh city core has been effectively characterised to test all possible future scenarios, and 4) testing Riyadh's transport future scenarios fusing Policy transfer angle. This research aims to serve all researchers and transport specialists at all executive levels from the higher authority to the transport engineers which lead to save time, effort and money.

Appendix A: List of References

- 59steps. (2015). Postcard from Riyadh – A Journey to Work. Available:
<https://59steps.wordpress.com/2015/11/05/postcard-from-riyadh-a-journey-to-work/>.
Last accessed 10-02-2017.
- Abdullah, W (2012). Large urban developments as the new driver for land development in Jeddah, Transport research art A, 36-46
- Abourahme, N. and M. Jayyusi (2011) The will to revolt and the spectre of the Real: reflections on the Arab moment. City 15, 625-30.
- ADA. (2015). Public Transport Study For the City of Arriyadh: Pilot Project - Phase I (Executive Summary). Riyadh: Ar-Riyadh Development Authority.
- AFP. (2016). \$22.5 billion Riyadh Metro ‘a race against time’. Available:
<http://english.alarabiya.net/en/business/aviation-and-transport/2014/10/30/-22-5-billion-Riyadh-Metro-a-race-against-time-.html>. Last accessed 11th Apr 2017.
- AL OMRAN, A. (2014). Bus Ride in Riyadh Before Saudi Capital Upgrades its Public Transport. Available: <http://blogs.wsj.com/middleeast/2014/04/03/bus-ride-in-riyadh-before-saudi-capital-upgrades-its-public-transport/>. Last accessed 12th Jul 2015.
- Al-Dubikhi, S. (2007). Exploring the Potential for Successful Public Transport in Riyadh. Melbourne: The University of Melbourne, Australia.
- Al-Fouzan, S. (1995). Reducing Car-Dependence in Ar-Riyadh City through the Integration of Land-use Planning and Transport. Unpublished PhD, Department of Architecture and Building Science, Strathclyde, Glasgow, UK.
- Al-Fouzan, S. (2011). Using car parking requirements to promote sustainable transport development in the Kingdom of Saudi Arabia Saleh Abdulaziz. Cities. 10 (29), 201-211.
- Al-Hathloul, S. (2002). Riyadh Architecture in One Hundred Years. Paper presented at the Darat al Funun on April 21, 2002, Amman.
- Al-Mosaind, M. (2001). The Effect of Changes in Land Use Distribution on Travel Patterns in Riyadh, Saudi Arabia. Paper presented at the Conference of Planning for Cities in the 21st Century: opportunities and Challenges (WPSC), Shanghai

- AlGadhi, S. (1994). Evaluation of Performance of Riyadh Urban Public Transportation Services. *Transportation Research Record*, 1433, 10-15.
- Aljoufiea, M., Zuidgeest, M., Brussel, M. and Maarseveen, M.,(2013); Spatial-temporal analysis of urban growth and transportation in Jeddah City-Saudi Arabia; *Cities* 31; p: 57-68.
- Almonte, Ana M; Abdel-Aty, Mohamed A. (2010). Exploring the Level of Service and Traffic Safety Relationship at Signalized Intersections. *ITE*. 6 (80), 18-24.
- Alqhatania, M., Bajwaa, S. and Setunge, S. (2012). Land-Use Transport Interaction: A Comparison of Melbourne, Riyadh. *Procedia - Social and Behavioral Sciences* , 3 – 13
- Alskait, K., McDonald, M., & Hassounah, M. (1997). The impact of urban arterial cross section on abutting property values and rents: The case of Riyadh, Saudi Arabia. *Transport Policy*, 4(1), 49-56.
- Amin A. and Thrift, N. (2002) *Cities: Reimagining the urban*. Polity Press, Cambridge.
- Anas, A. and T. Hiramatsu (2012). "The effect of the price of gasoline on the urban economy: From route choice to general equilibrium." *Transportation Research Part A: Policy and Practice* 46(6): 855-873.
- Banister, D. (2005). *Transport and Urban Development*. Second edition. Published by Taylor & Francis.
- Banister, D. and S. Marshall (eds.) (2007) [Land Use and Transport Planning - European Perspectives on Integrated Policies](#). London: Elsevier.
- Barnett, C. (2011) Theory and events. *Geoforum* 42, 26-35.
- Bazghandi, A. (2012). Techniques, advantages and problems of agent based modeling for traffic simulation. *Int J Comput Sci*, 9(1), 115-119.
- BBC. (2013). Why can't women drive in Saudi Arabia?. Available: <http://www.bbc.co.uk/newsround/24691034>. Last accessed 12th Jul 2015.
- Bellei, G., Gentile, G., Papola, N. (2002). Network pricing optimization in multi-user and multimodal context with elastic demand. *Transportation Research Part B* 36 (9), 779-798.
- Bertini, R. (2006). You Are the Traffic Jam: An Examination of Congestion Measures. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

- Bhatta, B., Saraswati, S. and Bandyopadhyay, D. (2010). Quantifying the degree of freedom, degree of sprawl and degree of goodness of urban growth from remote sensing data. *Applied Geography* 30(1); p: 96-111.
- Brenner, N., Madden, D. J., and Wachsmuth, D. (2011) Assemblage urbanism and the challenges of critical urban theory. *City* 15, 225-40.
- Brenner, N., Marcuse, P., and Mayer, M. (2009) Cities for people, not for profit: Introduction, *City* 13, 176-84.
- Cairometro. (2017). cairometro. Available: http://cairometro.gov.eg/HomePage_Arabic.aspx. Last accessed 11th Dec 2017.
- Castells, M. (1977) The urban question. MIT Press, Cambridge, MA.
- Cervero, R. "Congestion relief: the land use alternative." *Journal of Planning Education and Research* 10.2 (1991): 119-130.
- Clark, C (2003). Transport - Maker and Breaker of Cities. In: *Urban Transport*. Edward Elgar Publishing Incorporated. Classics in Transport Analysis, Volume: 8. Publisher: Edward Elgar Publishers
- Clegg, J., Smith, M., Xiang, Y. and Yarrow, R. (2001). Bi level programming applied to optimising urban transportation. *Transportation Research Part B* 35 (1), 41–70.
- Cochrane, A. (2007) Urban policy: a critical approach. Blackwell, Oxford.
- Cochrane, A. and Ward, K. (2012) Researching the geographies of policy mobility: confronting the methodological challenges, *Environment and Planning, A* 44, 5-12.
- Cochrane, A., Peck, J., and Tickell, A. (1996) Manchester plays games: exploring the local politics of globalisation, *Urban Studies* 33, 1319-36.
- Cox, K. (1998) Spaces of dependence, spaces of engagement and the politics of scale, or: looking for local politics. *Political Geography* 17, 1-23.
- Cristina, T. and McCann, E. (2013) Geographies of Policy Motilities. Simon Fraser University, Department of Geography, Simon Fraser University. *Geography Compass* 7/5: 344-357.
- Davies, J. and Imbroscio, D. (eds.) (2009) Theories of urban politics (second edition). Sage, London.

- Dawson, P. (2003). Analysing the effects of spatial configuration on human movement and social interaction in Canadian Arctic communities. In 4th International space syntax symposium, London.
- DeLanda, M. (2006) A new philosophy of society: assemblage theory and social complexity. New York, Continuum.
- Dietzel, C., Herold, M., Hemphill, J. and Clarke, KC 2005, 'Spatio-temporal dynamics in California's central valley: empirical links to urban theory', *International Journal of geographic information science*, vol. 19, no. 2, pp. 175-195
- Dolowitz, P. and Marsh, D., (2000)The Role of Policy Transfer in Contemporary Policy-Making'', in *Governance: An International Journal of Policy and Administration*, vol. 13,
- Doxiadis and the First Strategic Plan for Riyadh Saudi Arabia (1968-1972). Georgia Institute of Technology: Doctor of Philosophy in Architecture. 43-135.
- Duranton, G. and Matthew. A. "Urban growth and transportation." *Review of Economic Studies* 79.4 (2012): 1407-1440.
- Ecola, Liisa, and Thomas Light. "Equity and congestion pricing." *Rand Corporation* (2009): 1-45.
- Eliasson, J., M. Börjesson, D., Amelsfört, K., Brundell, F. and Engelson, L (2013). "Accuracy of congestion pricing forecasts." *Transportation Research Part A: Policy and Practice* 52(0): 34-46.
- Elsheffi, Y. (1992). *Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods*. Published by; Prentice- Hall, Inc.
- Europe Directorate General for Energy and Transport. (2010). Principles of successful high quality public transport operation and development. PROCEED. Project, 9-10.
- Fan, F., Wang, Y., Qiu, M., and Wang, Z. (2009). Evaluating the temporal and spatial urban expansion patterns of Guangzhou from 1979 to 2003 by remote sensing and GIS methods. *International Journal of Geographical Information Science*, 23(11), 1371–1388.

- Farahani, R., Miandoabchi, M., Szeto, W., Rashidi, H., (2013). A review of urban transportation network design problems. *European Journal of Operational Research* 229 (2013) 281–302
- Farias, I. and Bender, T. (2010) *Urban assemblages: how actor network theory changes urban studies*. Routledge, London.
- French, S., Leyshon, A., and Thrift, N. (2009) A very geographical crisis: the making and breaking of the 2007/2008 financial crisis. *Cambridge Journal of Regions*.
- Gubins, S. and E. T. Verhoef (2014). "Dynamic Bottleneck Congestion and Residential Land Use in the Monocentric City." *Journal of Urban Economics* 80: 51-61.
- Gudmundsson, H., Ericsson, E., Hugosson, M. and Rosqvist, L. (2009) Framing the role of Decision Support in the case of Stockholm Congestion Charging Trial, *Transportation Research part A, Policy and Practice*, Volume 3.
- Gupta, A. (2014). 08. applied microeconomics. Available: <https://www.slideshare.net/AshishGupta21/08-applied-microeconomics>. Last accessed 10th June 2017.
- Hillier, B., & Iida, S. (2005). Network and psychological effects in urban movement. *Lecture Notes in Computer Science*, 3693, 475.
- Hobbs, A. and Harriss, L. (2013). Peak car use in Britain. Available: <https://www.parliament.uk/documents/commons-committees/transport/POST-briefing-on-peak-car.pdf>. Last accessed 10th Apr 2017.
- Hoyt, L. (2006). Importing Ideas: The Transnational Transfer of Urban Revitalization Policy. *International Journal of Public Administration*. 29 (1-3), 221-243.
- Ison, S. and Anthony, G. (2011). Transferability of urban transport policy. *Transport Policy*. 18 (3), 489-491.
- ITS United Kingdom. (2016). What is ITS. Available: <http://www.itsuk.org.uk/about/aboutus>. Last accessed 7/10/2017.
- Jenelius, E. Lars-Göran Mattsson (June, 2012) Road network vulnerability analysis of area-covering disruptions: A grid-based approach with case study. *Original Research Article Transportation Research Part A: Policy and Practice*, Volume 46, Issue 5, pp. 746-760.

- Jörnson, G. (2005). *Urban Transport Development*. NY: Springer Berlin Heidelberg New York. 24-26.
- KaysI, I.and Chaaban, F. (2010). Arab environment. *Green Economy*. 5 (1), 133-160.
- Koppelman, F., Bhat, B. and J. L. Schofer (1993). "Market research evaluation of actions to reduce suburban traffic congestion: Commuter travel behavior and response to demand reduction actions." *Transportation Research Part A: Policy and Practice* 27(5): 383-393.
- Kottenhoff, K. and Brundell, K. (2009). "The role of public transport for feasibility and acceptability of congestion charging – The case of Stockholm." *Transportation Research Part A: Policy and Practice* 43(3): 297-305.
- Kumar, S. "Satisfaction of Tourists with Public Transport: An Empirical Investigation in Dubai." *Journal of Travel & Tourism Marketing*, vol. 31, no. 8, 2014, pp. 1004–1017.
- Laodme.com. (2016). Cost of Diesel in Saudi Arabia Today. Available: <https://www.load-me.com/diesel-fuel-cost-in-saudi-arabia>. Last accessed 10-02-2017.
- Leeming, J., Mackay, G. and Pole, K. (2007). *Reprint of Road Accidents: Prevent or Punish*. Wrexham: Quinta press. eBook.
- Litman, T. "Transportation Affordability." *Transportation* 250 (2017): 360-1560.
- Litman, T. *Evaluating public transit benefits and costs*. Victoria Transport Policy Institute, 2015.
- Liu, R., May, T. and Shepherd, S. (2011). "On the fundamental diagram and supply curves for congested urban networks." *Transportation Research Part A: Policy and Practice* 45(9): 951-965.
- Liu, S., Triantis, K. and Sarangi, S. (2010). "A framework for evaluating the dynamic impacts of a congestion pricing policy for a transportation socioeconomic system." *Transportation Research Part A: Policy and Practice* 44(8): 596-608.
- LOCKABY, B., ZHANG, J., MCDANIEL, TIAN, H., and PAN, S. (2005). *Interdisciplinary research at the Urban–Rural interface: The WestGa project*. *Urban Ecosystems*. 8.1 (1), 7-21.

Los Angeles metropolitan transportation authority. (2016). Ridership. Available: <https://www.metro.net>. Last accessed 25-01-2017.

Marsdena, G., Stead, D. (May 2011). Policy transfer and learning in the field of transport: A review of concepts and evidence. *Transport Policy*. 18 (3), 492-500.

Martínez, C. (2004). Policy transfer in the EU: a model for MENA countries. *Universidad de Granada, Spain*. 3 (1), 1-5.

Mathew, T. and Krishna, K. (2007). Traffic stream models. Introduction to Transportation Engineering. NPTEL: NPTEL. 33.1-33.5.

McCann, E (2011) Urban Policy Mobilities and Global Circuits of Knowledge: Toward a Research Agenda, *Annals of the Association of American Geographers*, 101:1, 107-130

McCann, E (2011) Urban policy mobilities and global circuits of knowledge: Toward a research agenda, *Annals of the Association of American Geographers*, 101.1, pp. 107-30.

McCann, E and Ward, K (eds) (2011) *Mobile Urbanism: Cities and policy making in the global age*. University of Minnesota Press, Minneapolis.

MCGUIRE, P. (2017). Portland Metro bus service had record-breaking ridership in 2016. Available: <http://www.pressherald.com/2017/01/25/portland-area-metro-had-record-breaking-ridership-in-2016/>. Last accessed 25-01-2017.

Metro & Evening Standard. (2016). METRO: READERSHIP & DISTRIBUTION. Available: <http://www.metroclassified.co.uk/productsandaudiences/readdistribution>. Last accessed 25-01-2017.

Metropolitantojubilee. (2013). LONDON: THE UNDERGROUND RAILWAY. Available: <https://metropolitantojubilee.wordpress.com/present-conditions/>. Last accessed 22nd May 2017.

Meyer, M. and Miller, E. (2001). *Urban transportation planning* (2nd ed.). New York: McGraw Hill.

Middleton, D. (2009). *Growth and Expansion in Post-War Urban Design Strategies*: C.

- MOT. (2015). The future of transport. Available:
<https://www.mot.gov.sa/Ar/FutureTransport/Pages/FutureTransport.aspx>. Last accessed 20 Oct 2016.
- MOT. (2016). PTA introduction. Available:
<https://www.mot.gov.sa/Ar/Pages/default.aspx>. Last accessed 17th Apr 2017.
- MTA. (2016). Introduction to Subway Ridership. Available:
<http://web.mta.info/nyct/facts/ridership/>. Last accessed 25-01-2017.
- Nishi, R., Tomoeda, A., Shimura, K. and Nishinari, K. (2013) Theory of jam-absorption driving, *Transportation Research Part B* 50, pp: 116–129.
- Nitzsche, E. and Tscharaktschiew, S. (2013). "Efficiency of speed limits in cities: A spatial computable general equilibrium assessment." *Transportation Research Part A: Policy and Practice* 56(0): 23-48.
- Nulman, E (2015) Dynamic interactions in contentious episodes: social movements, industry, and political parties in the contention over Heathrow's third runway, *Environmental Politics*, 24:5, 742-761
- OECD (2007) *Managing Urban Traffic Congestion*, Summery Document, Joint Transportation Centre.
- OECD/GD, (1996). *Pollution Prevention and Control, Environmental Criteria for Sustainable Transport*. Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST), Paris. P:14
- Owens, S (1998) *Urban Transport and Land Use Policies in East and West: Learning from Experience*. *International Journal Environment and Pollution*, Vol.10, No.1, pp.104-125
- Panagiotopoulos, V. (2016). The Los Angeles metro is great. Available:
<http://www.citymetric.com/transport/los-angeles-metro-great-so-why-aren-t-people-using-it-2742>. Last accessed 21 Aug 2017.
- Paris by train. (2016). Paris Metro RER Maps, Tickets, Schedules, Route Planner and Guides. Available: <http://parisbytrain.com/paris-metro/>. Last accessed 25-01-2017.
- Peck, J and Theodore, N (2010) Mobilizing Policy: Models, Methods and Mutations in *Geoforum*, 41, 2, pp. 169-74.

Peck, J. (2011) Geographies of Policy: from transfer-diffusion to mobility-mutation, *Progress in Human Geography*, 35, 6, pp. 773-97.

Pengonda, P. (2014). Petrol prices in India lower than in many countries. Available: <http://www.livemint.com/Money/tLB3JnHJyDuGn74rQSmzzH/Petrol-prices-in-India-lower-than-in-many-countries.html>. Last accessed 12th Jul 2015.

Preston, J. (2010); What's so funny about peace, love and transport integration?; *Research in Transportation Economics*. Elsevier Ltd. Vol:29. P: 329 338

Quamar, M. (2015). Islamic Modernism and Saudi Arabia: Confluence or Conflict. *SAGE Publications*. 2 (1), 71-87.

Rommerts, M. (2012). THE ROLE OF EU-SUPPORTED PROJECTS IN POLICY TRANSFER IN URBAN TRANSPORT. *University College London*.

Sabo, R. and Boone, E. (2013). *Statistical Research Methods*. New York: Springer . 1-24.

Schaller, B. "New York City's congestion pricing experience and implications for road pricing acceptance in the United States." *Transport Policy* 17.4 (2010): 266-273.

Smith, S. (2016). Kuala Lumpur's ambitious urban rail plan starts to deliver results. *international railway journal*. 1 (1), 204.

Soguk, N (2011) Uprisings in 'Arab Streets' revolutions in 'Arab Minds'. *A Provocation*. *Globalizations*, 8, 5, pp. 595-9.

Stead, D. (2001) Relationships Between Land Use, Socio- Economic Factors and Travel Patterns in Britain, *Environment and planning B: Planning and Design*, Vol.28, pp.499-528

TALUKDAR, M. (2013). Framework for Traffic Congestion Management. *Economia. Seria Management*. 15 (1), 55-64.

Thomson, J. (1978). *Great Cities and Their Traffic*. London: Penguin Books. 109-112.

Transit Oriented Development Institute. (2002). *Transit Oriented Development Institute*. Available: <http://www.tod.org>. Last accessed 18th Oct 2016.

Transport for London. (2017). CONGESTION CHARGE. Available: <https://tfl.gov.uk/modes/driving/congestion-charge>. Last accessed 30 Aug 2017.

- Tsai, F. and Chu, C. (2010). "Analysis of the optimal length of road expansion – A case study of the Taipei metropolitan area." *Transportation Research Part A: Policy and Practice* 44(3): 147-158.
- Ubillos, J. (2008). "The costs of urban congestion: Estimation of welfare losses arising from congestion on cross-town link roads." *Transportation Research Part A: Policy and Practice* 42(8): 1098-1108.
- UITP (2014). Enhancing integration of public transport: Saudi Arabia, an example in the Mena region? Available: <http://www.uitp.org/enhancing-integration-public-transport-saudi-arabia-example-mena-region>. Last accessed 17th Oct 2016.
- Victoria Transport Policy Institute (2011), *Transportation Cost and Benefit Analysis II – Congestion Costs Institute*, August. (www.vtpi.org).
- Victoria Transport Policy Institute. (2014). Online TDM Encyclopedia. Available: <http://www.vtpi.org/tdm/index.php#stakeholders>. Last accessed 13-02-2017.
- Vigar, G., Healey, P., Hull, AD. and Davoudi, S., 2000, *planning, Governance and Spatial Strategy in Britain: an institutional analysis*, London, Macmillan (published in the US by St Martins Press: New York).
- Vuchic, V. R. (1999). *Transportation for Livable Cities*. New Brunswick, New Jersey: Centre for Urban Policy Research.
- VVS public transit association. (2016). VVS Stuttgart. Available: <http://en.vvs.de/home/>. Last accessed 25-01-2017.
- Wardman, M. and J. Ibáñez, N. (2012). "The congestion multiplier: Variations in motorists' valuations of travel time with traffic conditions." *Transportation Research Part A: Policy and Practice* 46(1): 213-225
- Wardmana, J. and Ibáñezb, N. (2014). The congestion multiplier: Variations in motorists' valuations of travel time with traffic conditions. *Transportation Research Part A: Policy and Practice*. 46 (1), 213–225.
- Wegener, M. (2009); *Possible Future Transport and Land Use Strategies for Sustainable Urban Development in European Cities* Urban and Regional Research; Dortmund, Germany.

- Wei, J., Xia, W., Guo, W. and Marinova, D. (2013); Urban transportation in Chinese cities: An efficiency assessment; *Transportation Research Part D* 23; p: 20–24.
- Williams, K. (Ed) (2005) *Spatial Planning, Urban Form and Sustainable Transport*, Aldershot: Ashgate.
- Winslott-Hiselius, L., K. Brundell-Freij, Å. Vagland and C. Byström (2009). "The development of public attitudes towards the Stockholm congestion trial." *Transportation Research Part A: Policy and Practice* 43(3): 269-282.
- Yusuf, A., Aina, Johannes, H., Merwe, V. and Alshuwaikhat, M. Urban Spatial Growth and Land Use Change in Riyadh: Comparing Spectral Angle Mapping and Band Ratioing Techniques. *Proceedings of the Academic Track of Free and Open Source Software for Geospatial, incorporating the Geo Information Society of South Africa* (29 September – 3 October, 2008).
- Zadeh, A and Rajabi, A (2013). Analyzing the effect of the street network configuration on the efficiency of an urban transportation system. *Cities* 31 pp: 285–297.
- Zheng, H., Nava, E. and Chiu, Y. (2011). Evaluating active traffic and demand management strategies for congested tourism traffic corridor.
<http://ieeexplore.ieee.org.ezproxy1.hw.ac.uk/xpl/mostRecentIssue.jsp?punumber=6069628>. 1 (1), 2015-2020.

Appendix B: letters of work qualification

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



المملكة العربية السعودية

الهيئة العليا

لتطوير مدينة الرياض

To whom it may concern;

This is to state that Mr. Majid Aldalbahi, Ph.D. student at Heriot-Watt University in the UK, has visited the Arriyadh Development Authority on December 22 . 2015 in Riyadh, where he presented the results of his research in the field of Urban Planning with specific interest in the area of " traffic simulation" .

Mr. Aldalbahi demonstrated in his presentation the application of traffic microsimulation models on the commercial spine in the city of Riyadh .

The outcome of the microsimulation models demonstrated the applicability of Mr. Aldalbahi research. The audience who attended the presentation valued the topic of the presentation and agreed that the resulting microsimulation models can be once completed and calibrated for the traffic situation in Riyadh, very instrumental in addressing and alleviating the traffic congestion problem in the city of Riyadh.

We believe that Mr. Aldalbahi research, has great potential to contribute to solving the growing traffic congestion problems in areas of high urban activities.

It is evident from the methodology of the research that when the research is completed and validated , its results can be applied in other areas of the city of Riyadh, and in other cities of the Kingdom of Saudi Arabia, where the socioeconomic characteristics and travel behaviors are similar.

Sincerely

Ahmad Assubail
General Director
Urban Strategic Planning
Arriyadh Development Authority

الهيئة العليا لتطوير مدينة الرياض
الشؤون الإدارية (١)

ARRIYADH DEVELOPMENT AUTHORITY

مركز المشاريع والتخطيط

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تلفون ٣٣٣١ - ٤٨٨ (٠١١) فاكس ٩٣٣١ ٤٨٢ (٠١١)

الرقم :
التاريخ :
المرفقات :

بسم الله الرحمن الرحيم



المملكة العربية السعودية

وزارة النقل

٢٨١

مشهد

المحترم

إلى من يهمه الأمر
السلام عليكم ورحمة الله وبركاته

تشهد الإدارة العامة لخدمات الطرق بوزارة النقل أنه تقدم لنا الطالب/ ماجد بن محمد الدلحي والذي يدرس الدكتوراه في مجال التخطيط العمراني بجامعة (هيروت وات) في المملكة المتحدة، وقد قام بإجراء بعض المقابلات مع متخذي القرار ومديري الإدارات المختصة، حيث تطرق في هذه المقابلات للحديث والنقاش عن تأثير التخطيط العمراني على النقل والازدحام المروري في مدينة الرياض.

وتقبلوا تحياتنا،،،،

مدير عام إدارة خدمات الطرق

المهندس/ عمران بن محمد العمران

عنه المهندس/ طارق بن مصطفى قسبي

١٤٣٧/٤/٢٢



Appendix C: Riyadh model CERTIFICATE



08 August 2017

Institute for Infrastructure and Environment
School of the Built Environment
Heriot-Watt University
Edinburgh
EH14 4AS

For the attention of Majid Aldalbahi, PhD Researcher

Dear Majid,

Congratulations on the successful completion of your research project using Paramics Discovery. As far as we know you are the first person to use Paramics Discovery to develop a model of the highway network in Riyadh.

The model you developed covers a large area and simulates significant volumes of traffic on multi-lane highways - a challenge for any professional transport modeller to build and calibrate.

Now that you have created this Paramics Discovery model of Riyadh it provides an excellent opportunity for further studies of the Riyadh transport system.

It has been our pleasure to support you during this project as you have developed in your understanding and skill as a traffic modeller. We wish you all the very best for the future.

Yours sincerely,



Malcolm Calvert
Paramics Director

Paramics Microsimulation is a division of SYSTRA Limited
37 Manor Place
Edinburgh EH3 7EB
Tel: 0131-225 7900
Fax: 0131-225 9229

Appendix D: interviews transcript

Participant 1:

Name: Eng. Tariq Qassi

Occupation : Manager of Safety and Roads Services at Ministry of Transportation.

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Poor planning in government departments, schools and universities, The lack of public transport

Question3. What is Riyadh doing about the problem?

Metro project, Starting to create e-government services and Implementation of ITS

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

USA, Turkey, France, UK

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

Saudi Arabia’s major cities must start their own public transport systems, as a matter of some urgency.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes, it is very important

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

Yes. it’s time to create more suburbs and encourage sustainable development.

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

It is obvious that the problem is complicated between both the governmental aspects and social responsibility.

Question9. What should be done to face the problem?

Thinking about reducing private car use

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

One of the main ideas for shifting people from private car use to PT (advertising, encouragement, free tickets and look at other cases worldwide).

Question11. In your opinion, what do you think are the main barriers to change?
What are the main barriers preventing people from relying on private cars as they do now?

There are no strict roles on the drivers. Easy to get a private car and driving licence

Question12. How do you see Riyadh looking in the future? What will life be like?
How will people work here and enjoy leisure? What travel modes will dominate?
What problems will be solved?

New projects such as the Riyadh Metro and more public transport will absolutely reduce congestion. Transport modes will become easier and more environmentally friendly.

Participant 2:

Name: Eng. Omran Elomran

Occupation : Executive Principal Manager at Ministry of Transportation

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Poor planning, ministries locations in the city centre. The establishment of large-scale projects and road works

Question3. What is Riyadh doing about the problem?

There's obvious effort from all departments to study the problem and potential solutions

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Malaysia, UK, Japan, USA

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

I think demand for public transport will increase if there are strict controls on private car use,

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes, there is an urgent need to get unused lands inside the city boundaries, and to connect them with other aspects of city services.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

In some parts of city, yes, we have reached our growth limits. On other hand, as I said, there is a lot of unused land which should be developed.

Question8. Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem?

The municipality: due to the building licence. Road users: because they have to obey the regulations

Question9. What should be done to face the problem?

We should encourage our people and put more effort into solving the problem. Create a high committee for traffic problems

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

Engaging people to discuss the issues is one of the key factors, especially those with good experience in that field.

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

There is no PT. Destinations are too far away from each other

Question12. How do you see Riyadh looking in the future? What will life be like?

How will people work here and enjoy leisure? What travel modes will dominate?

What problems will be solved?

I think Riyadh will become one of the world's most developed capital cities. Public transport facilities will enhance the economy and create easy connections between the different parts of the city.

Participant 3:

Name: Eng. Ahmad Esabeel

Occupation : Urban Planning Manager at Arriyadh Development Authority (ADA).

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Lack of public parking and Commercial land use on the streets

Question3. What is Riyadh doing about the problem?

Starting to use ITS, Traffic police are enforcing strict fines and penalties, Creating more parking spaces and Replanning different parts of the city

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Developed countries – particularly those with PT systems

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

Demand for transport is increasing, and there must be solutions, namely: public transportation, traffic adjustments through the use of modern techniques, commitment of land use and its development.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes. And we have to get out of the grid network patterns of planning, which have led to an increase in private cars.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

Yes, we have reached our growth limits and we are working to create new limits every five years. And progress has been made in terms of developing on unused land across the city.

Question8. Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem?

All departments you have listed own the problem and so must find solutions

Question9. What should be done to face the problem?

Cooperating with other departments. Creating a research centre to study these problems and come up with solutions

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

By showcasing public transport plans and projects and listening to feedback and ideas.

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

No effective public transport system

Question12. How do you see Riyadh looking in the future? What will life be like?

How will people work here and enjoy leisure? What travel modes will dominate?

What problems will be solved?

I think Riyadh is going to be a developed city once it's implemented its strategic plans and projects. Life will become easier in terms of business, social activities and entertainment.

Participant 4:

Name: Jalal Nafaleh

Occupation : Chief Transport Planner at Arriyadh Development Authority (ADA)

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Work and school trips

Question3. What is Riyadh doing about the problem?

Developing PT and Implementing traffic management systems

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

London

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

It's the right time for efficient demand management.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes, Riyadh should consider transit- oriented development TOD.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

We should revise building regulations

Question8. Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem?

All of them

Question9. What should be done to face the problem?

Good planning, more research

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

Everyone must participate

Question11. In your opinion, what do you think are the main barriers to change?
What are the main barriers preventing people from relying on private cars as they do now?

The main reason is the absence of public and school transport

Question12. How do you see Riyadh looking in the future? What will life be like?
How will people work here and enjoy leisure? What travel modes will dominate?
What problems will be solved?

Riyadh will be the jewel of the Middle East! Traffic future will be attracted with the transportation of public this will be more participate public opinion.

Participant 5:

Name: Mohammed Mujeeballah Khan

Occupation : Traffic Modeller at Arriyadh Development Authority (ADA)

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

No alternative modes of transport, Lack of public transport, Land use

Question3. What is Riyadh doing about the problem?

Restudying road capacity, PT and traffic management, ITS

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

All developed countries

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

Traffic procedures in place to make informed decisions, as well as having good traffic management measures to create an efficient transport system.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Riyadh has a structural plan, zoning etc., the only thing is to implement this on ground. Transport and land use will be integrated by doing so.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

The Riyadh master plan takes to the growth in terms of residential neighbourhoods. And it will improve at an accelerating rate.

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

All of them

Question9. What should be done to face the problem?

Working to estimate the impact and prioritise that impact. Cooperating with other departments to create a long-term strategy

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

By holding an annual meeting and conferences to engage people and encourage them to participate.

Question11. In your opinion, what do you think are the main barriers to change?
What are the main barriers preventing people from relying on private cars as they do now?

Lack of PT and low petrol prices

Question12. How do you see Riyadh looking in the future? What will life be like?
How will people work here and enjoy leisure? What travel modes will dominate?
What problems will be solved?

Riyadh is the one of the biggest cities in the world, so it has a rapidly ongoing population. There are continuous studies and research into developing solutions like other capital cities worldwide. And we should take into account newest methods and technology.

Participant 6:

Name: Dr. Abdulazeez Alauhali

Occupation : Chief Executive at Public Transport Authority.

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Private car dependency, Lack of public transport, Peak times across various activities, Social trips and Current road works

Question3. What is Riyadh doing about the problem?

Public transport, Traffic management and Road modification and development

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Singapore, London, Paris, North America, Australia

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

Provide sufficient capacity for both private cars and public transport. Demand for public transport must be started now; it will cost more if there’s a delay.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes, we have to change our cities from two aspects: first, limitation of horizontal growth. Second, we should consider our housing philosophy and what we are need exactly in our houses elements and content.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

Commercial and economic development is the core thing in terms of providing jobs and improving the quality of life. We should consider consumer activities, and productive activities. Thus, we should increase the available space for productive activities and so on.

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

These departments are in charge collectively

Question9. What should be done to face the problem?

Good forward planning

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

One of the objectives of the Public Transportation Authority is to raise awareness of the importance of PT and its benefits to society.

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

Private car use will still be attractive even in communities with public transport, but change starts from two points:

- Policy change on private car use
- Motivate environmental conservation and the national economy

Question12. How do you see Riyadh looking in the future? What will life be like?
How will people work here and enjoy leisure? What travel modes will dominate?
What problems will be solved?

Riyadh means paradise in Arabic. It should be like its name!

Participant 7:

Name: Rafat Brbour

Occupation : Assistant Chief of Transport Department at Public Transport Authority

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Rapid city growth

Question3. What is Riyadh doing about the problem?

PT, Traffic management

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

UK, USA

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

All of the previous answers. Public transport, land use obligation, ITS.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

No limits on growth, management is the key

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

User problems should be solved by MOT, ADA and the municipality

Question9. What should be done to face the problem?

Having an efficient public transport system. Encouraging people to use it

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

Without community engagement, there is no solution

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

No practical experience

Question12. How do you see Riyadh looking in the future? What will life be like?
How will people work here and enjoy leisure? What travel modes will dominate?
What problems will be solved?

The municipality is working on a lot of new projects that will provide great solutions, as mentioned before

Participant 8:

Name: Eng. Khalaf Aldalbahi

Occupation : Director of Design & Transportation Department at Riyadh Municipality

Question1. Do you think that Riyadh suffers from congestion?

yes

Question2. What are the possible causes of this congestion?

Lack of PT, Poor planning

Question3. What is Riyadh doing about the problem?

Developing the road network, Cooperating with other transportation departments and Associating with ITS

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

All developed countries

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

The municipality has a good plan to deal with capacity including: developing junctions, making adjustments for traffic lights, creating new roundabouts and simulation software

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes. Land use and transportation should be integrated, and take into account growth limit restrictions.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

The rapid growth of Riyadh is a big challenge and the municipality has considered this growth, and its impact on land use

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

All departments

Question9. What should be done to face the problem?

Shifting people to use public transport. More consideration about land use and the shape of the road network

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

It is very important and the municipality must raise awareness of public transport

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

Shifting people to use public transport

Question12. How do you see Riyadh looking in the future? What will life be like?

How will people work here and enjoy leisure? What travel modes will dominate?

What problems will be solved?

I think Riyadh is going to be a capital city with an easy life that should take its place in the developed world phase

Participant 9:

Name: Eng. Yousef Al mutairi

Occupation : President of Shumaisi Municipality at Riyadh Municipality

Question1. Do you think that Riyadh suffers from congestion?

Yes

Question2. What are the possible causes of this congestion?

Private car dependency, Poor planning and Lack of PT

Question3. What is Riyadh doing about the problem?

PT, Traffic management and ITS

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

Los Angeles, Munich, Paris, Detroit, Dubai

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

Many studies and research have been conducted on road capacity and its capabilities so far.

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

The strategic master plan should deal with these aspects.

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

We should consider our building licence and its efficiency

Question8. Who owns the problem? Is it the Department for Transport’s problem to solve? The building licence people? Or is it the user’s problem?

All departments

Question9. What should be done to face the problem?

Creating a transport strategy. Considering other cases across the world

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

We must consider our culture and privacy needs and look at other examples to find perfect one that would apply to our case.

Question11. In your opinion, what do you think are the main barriers to change? What are the main barriers preventing people from relying on private cars as they do now?

Privacy, culture and low petrol prices

Question12. How do you see Riyadh looking in the future? What will life be like? How will people work here and enjoy leisure? What travel modes will dominate? What problems will be solved?

I think Riyadh is going to be a capital city with an easy life that should take its place in the developed world phase

Participant 10:

Name: Dr Faisal Fahad

Occupation : Former Director of Urban Planning Department at Riyadh Municipality

Question1. Do you think that Riyadh suffers from congestion?

yes

Question2. What are the possible causes of this congestion?

Migration to the city, Lack of PT, Road parking and traffic police efficiency

Question3. What is Riyadh doing about the problem?

PT, Traffic management and Road improvements

Question4. What examples around the world do you find particularly attractive in terms of dealing with transport capacity? Where do you look for best practice?

London, Japan, Washington, Frankfurt

Question5. What is your view about transport capacity – should we keep ‘predicting and providing solutions’ or is now the time to try and manage demand?

The Metro project has opened the door to all consultants to study the congestion impact and traffic demand management in Riyadh

Question6. What is your view on land use policies and urban sprawl – does the physical shape and layout of Riyadh need to change?

Yes

Question7. Are we reaching the limits of growth, or is the vision to enable more space for residents and commercial development?

The strategic master plan has been developed every five years

Question8. Who owns the problem? Is it the Department for Transport's problem to solve? The building licence people? Or is it the user's problem?

I think the municipality is largely responsible for the problem

Question9. What should be done to face the problem?

As discussed previously, all departments are involved in the problems and must find a solution together

Question10. What is your plan for engaging the community, or what is your alternative plan in the case of not engaging them?

By changing land use and telling people that transport is an important, attractive way of replacing and reducing private car use.

Question11. In your opinion, what do you think are the main barriers to change?

What are the main barriers preventing people from relying on private cars as they do now?

Changing policy on private car and road user is a key barrier

Question12. How do you see Riyadh looking in the future? What will life be like?

How will people work here and enjoy leisure? What travel modes will dominate?

What problems will be solved?

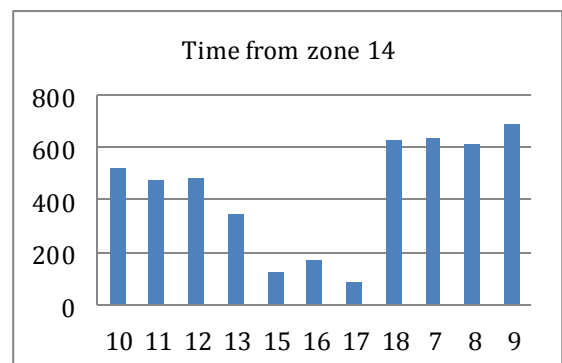
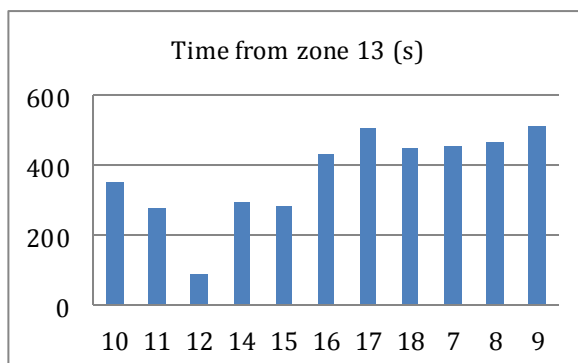
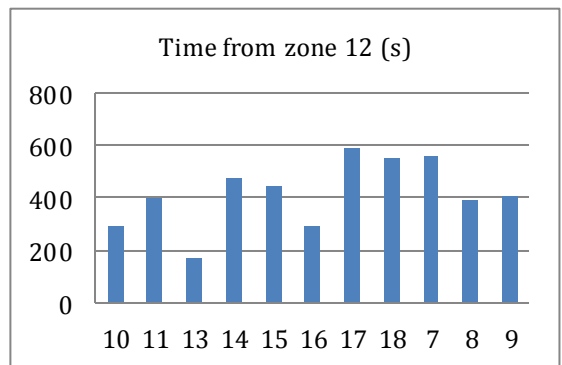
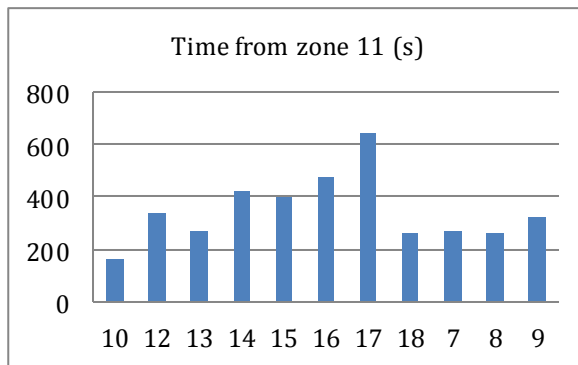
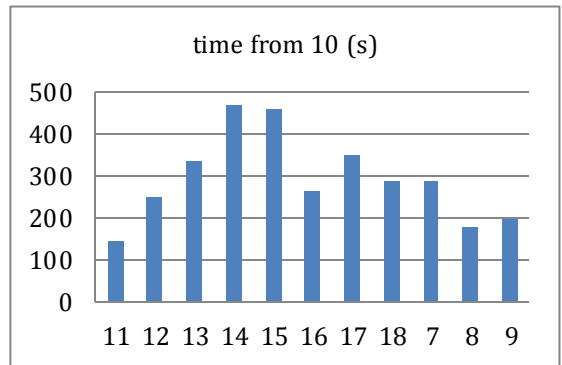
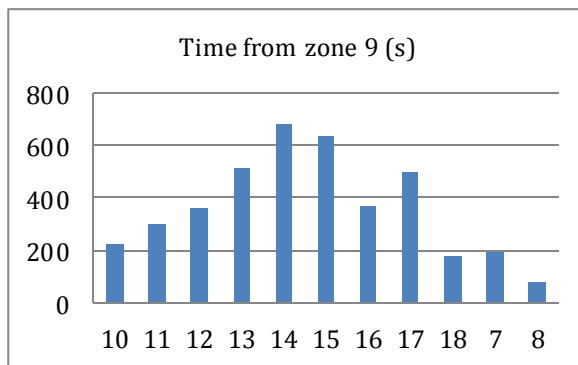
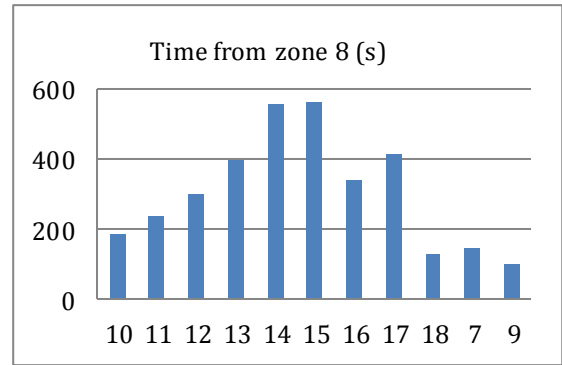
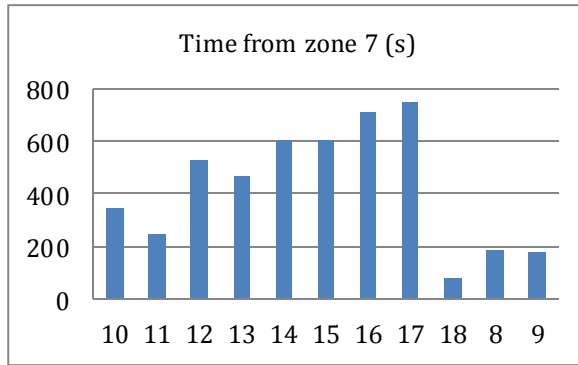
Easy travel, environmentally friendly and a strong economy

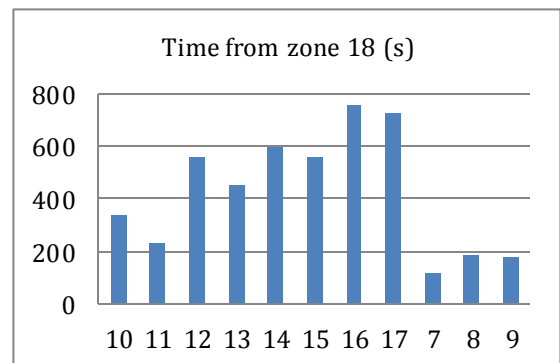
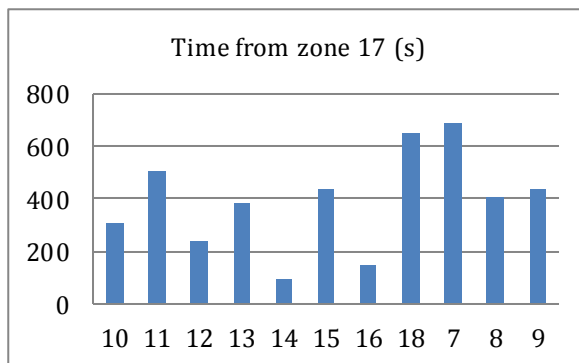
Appendix E: field work trip Gantt chart

Week start	Mission	Task
20/11/2015		travelling to Saudi
22/11/2015	Preparing interviews	preparing interview with public and making appointment with stockholders
29/11/2015		preparing interview with public and making appointment with stockholders, approaching to interview with public and stockholders (as possible), talks with ADA to carry out the traffic data
6/12/2015	interview and data collection	meeting the interviewee and record the interview. talks with ADA to carry out the traffic data
13/12/2015		meeting the interviewee and record the interview. talks with Municipality ADA to carry out the traffic data
20/12/2015		meeting the interviewee and record the interview. working with Municipality ADA to get the traffic flow and directions indicators and information. Visiting ministry of transportation
27/12/2015		meeting the interviewee and record the interview. working with Municipality ADA to get the traffic flow and directions indicators and information. Visiting ministry of Rural and municipal affaires
3/1/2016		meeting the interviewee and record the interview. working with Municipality ADA to get the traffic flow and directions indicators and information. Visiting ministry of interior
10/1/2016		meeting the interviewee and record the interview. working with Municipality ADA to get the traffic flow and directions indicators and information. Visiting ministry of finance
17/1/2016	Fitting data, Data pre-analysis	completing interview (if necessary) Translating interviews fitting and distinguishing data
24/1/2016		completing interview (if necessary) Translating interviews fitting and distinguishing data
31/1/2016		completing interview (if necessary) Translating interviews fitting and distinguishing data
7/2/2016		pre-analysis and testing data, data submission
14/2/2016		pre-analysis and testing data, data submission
21/2/2016		back to Edinburgh

Appendix F: detailed results for SMM

Time taken between destinations





Queue length

